Exploring the research landscape of convergence from a TIM perspective: a review and research agenda

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Abstract

Convergence at the level of science, technology, market or industry can increasingly be witnessed in a number of empirical settings. It is currently seen as one of the most important influence factors on and trigger for developing innovation strategies. This empirical relevance is mirrored by a surge in publications. Therefore, motivated by a highly dynamic but at the same time rather unstructured body of literature, this review offers a systematic and critical analyses of studies related to Technology and Innovation Management (TIM) research that address convergence from a processual perspective. Four major strands can be identified: (1) drivers and patterns of convergence, (2) anticipation of convergence, (3) strategic reactions to convergence, and (4) convergent products. A key finding of this review is that most contributions have been inward oriented, i.e. understanding the dynamics of convergence. A consequence of this inner focus is that the scientific discourse on convergence has to some degree unfolded independently from its theoretical underpinnings. To this end, this review provides a comprehensive framework of convergence research, including current challenges and emerging themes to address these challenges. The resulting research agenda serves as a starting point to inspire future studies of relevance for theory and conceptual development as well as managerial practice.

Keywords: converging industry; industry convergence; industry fusion; innovation strategy; knowledge recombination; technology convergence

1. Introduction to convergence as a setting for technology and innovation management research

The notion of convergence presents itself as a significant empirical phenomenon with an increasing relevance when it comes to new technology and innovation. In an overall managerial context, the concept of convergence was first used by Nathan Rosenberg to delineate convergence from "sequences of parallel and unrelated activities" in his article on changes in the machine tool industry during the second half of the 19th century (Rosenberg 1963). He employed the concept of convergence to describe processes that are commonly used by unrelated industry sectors and different stages of tool production. However, in today's time, convergence research is of growing empirical relevance as the impressive example of "NanoBioInfoTech" convergence (Schmulewitz et al. 2006, Maine et al. 2014) or the confluence of hitherto unrelated sectors due to the application of novel technology platforms, e.g. sensors enabling the Internet of Things (IoT) (Lim et al. 2018), demonstrate. These novel combinations of hitherto distant fields of science and technology impressively underline the blurring of boundaries beyond science and technology, thus also concerning products, markets, regulatory frameworks and entire industries (Gambardella and Torrisi 1998, Bröring et al., 2006, Curran et al. 2010, Gauch and Blind 2015, Kim et al. 2015).

Moreover, in addition to empirical relevance, convergence has emerged as a growing field in the Technology and Innovation Management (TIM) domain. However, it seems this surge in popularity has also brought about a rather unstructured body of literature. We observe that research on convergence has only gained momentum since the mid-1980s due to the developments in the information technology, consumer electronics and telecommunication (ICT) industry sectors (e.g. Wirtz 2001, Bierly and Chakrabarti 2001, Borés et al. 2003, Lee 2007). Although further areas of convergence such as nutraceuticals (Bornkessel et al. 2016), radio-frequency identification (RFID) (Karvonen and Kässi 2013), the bioeconomy (Golembiewski et al. 2015), nanotechnology (Allarakhia and Walsh 2012), logistics (Niemann et al. 2013), renewable energies (Jeong et al. 2016) and energy storage (Sick et al. 2019) or mechatronics (Freddi 2009) have been explored since.

The recent burst of interest in convergence is also reflected by an increase of semi-scientific stories in the business press, mentioning convergence as a major driver for innovation. Conferences on convergence and specific funding schemes, e.g. the NSF Convergence Accelerator (NSF 2020), have also been dedicated to this phenomenon. This rapid diffusion of the notion and the relevance of convergence in practice has not, however, been coupled with a similarly rapid and robust diffusion of its theoretical foundations. Similar to other emerging fields of research, there is a considerable lack of consistency with regards to definition, conceptualization and operationalisation across studies. To provide an example, technology convergence, as initially coined by Nathan Rosenberg, is referred to as technology fusion in other studies (Kodama 1992, Caviggioli 2016) and two-way technology convergence in others (Eilers et al. 2019). This example demonstrates the flux and inconsistency of terminologies. Hence, conceptual clarity and, thus, a common understanding of what convergence entails, is still developing in the TIM literature. Another example where conceptual clarity needs further elaboration is the definition and delineation of the steps of the convergence process. While some authors refer to the consecutive steps of science, technology, market and industry convergence (Curran et al. 2010) others refer to knowledge convergence (Hacklin 2005). Moreover, while convergence of technologies is well-researched (Gambardella and Torrisi 1998, Curran and Leker 2009, Suh and Sohn 2015, Venugopalan and Rai 2015, Han and Sohn 2016, Song et al. 2017), convergence of scientific fields (Kose and Sakata 2019, Jeong et al. 2018), markets (Schmidt et al. 2016) and finally industries (Sick et al. 2019, Geum et al. 2016) has not only been covered to a much lesser extent but also lacks consistent use of established theoretical concepts.

The previous examples only represent a small share of the vast variety of different areas of convergence research. However, they highlight the numerous challenges that scholars and practitioners involved with technology and innovation management face in a setting of convergence. Against this backdrop, there is a strong need for a review of the current body of literature which not only structures but also aims to bridge the different angles of extant convergence research into a holistic framework. Hence, this paper seeks to enable convergence scholars, but also more generally those working on technology dynamics and foresight, to position and connect their own work to the growing body of convergence-related literature from a TIM research perspective. The TIM field itself is rather interdisciplinary and integrates different perspectives from innovation economics over strategic technology and innovation management to new product development and the user perspective (Pitt et al. 2021, Linton and Thongpapanl 2004). We define the TIM domain by drawing upon the Technology and Innovation Management Division of the Academy of Management which was formed in 1987 with the aim to *´encourage interdisciplinary scholarship and dialogue on the management of innovation and technological change from a variety of perspectives, including strategic, managerial, behavioral, and operational issues.` (AOM 2020).* There is further evidence for a TIM-related literature body as a list of 50 relevant journals in the TIM domain can be found in Linton and Thongpapanl (2004) and of the most influencing TIM scholars in Thieme (2007) as well as in a recent bibliographic analysis spanning 20 years of research in TIM-related journals (Pitt et al. 2021).

In light of the above-mentioned scarce and less consistent discussion of convergence in the extant body of TIM literature, as well as the simultaneously high relevance and impact of convergence, the overall aim and contribution of the study is to provide an overview of the extant convergence research landscape. To this end, informed by Petticrew and Roberts (2006), this paper comprehensively reviews, appraises and synthesizes the literature on convergence and creates an integrated framework to highlight not only along which strands the growing body of convergence literature enfolds, but how it links to extant theory perspectives embedded in the larger field of management science. This attempt to develop a coherent framework seems extremely relevant, given that the absence of a coherent view on the convergence landscape and its conceptual foundations renders any cross-study comparison and the overall possibility for deeper understanding of the underlying mechanism of convergence processes difficult. This latent need within the literature to come to terms with the diverse understandings of convergence is likely to gain importance as this phenomenon itself becomes ever more empirically relevant and is applied to numerous examples of the confluence of different areas of science and technology in the near future. By means of such a systematic review on the extant convergence literature, the aim of this study is to:

1. Provide a concise overview of the current research landscape of convergence, identifying and analyzing strands of convergence research,

2. Identify the major lenses and theoretical foundations applied in the extant convergence literature body,

3. Integrate the different strands of convergence research, as well as identify emerging themes and avenues for future research.

The remainder of this study is organized as follows. Section 2 offers a delineation of the conceptual background of convergence research. Data and methods to conduct a systematic literature review are presented in Section 3. Section 4 contains findings with respect to the different strands of convergence research, while Section 5 offers a structured synthesis of the insights and avenues for further research. Section 6 concludes the study with implications and limitations.

2. Conceptualization of convergence in the TIM context

The speed of evolution of the convergence literature and the diversity of issues explored are still escaping scholars' efforts in capturing its ontology. With ICT as the first prominent field of convergence, many early definitions limit the phenomenon of convergence to the ICT domain (Nyström 2008). Given the growing relevance of convergence beyond ICT, convergence in this paper is inclusive of any field of application. Another problem for defining convergence is the plurality of terms used to describe the same phenomenon. In parallel to Rosenberg's offer of `technology convergence´, the same phenomenon has been referred to as `technology fusion' to describe a type of innovation that leads to breakthrough functions by combining at least two or more existing technologies into hybrid technologies (Kodama, 1992, Freddi 2009). Likewise, interdisciplinary and cross-disciplinary technology have been used to describe similar phenomena (Rafols and Meyer 2007, Morillo et al. 2001, Porter and Chubin 1985). However, the two latter terms refer to a short-term, temporary interdisciplinary action and not necessarily reflecting a long-lasting convergence process.

While these terms suggest that convergence predominantly occurs on a technological level, an OECD report in 1992 was among the first to acknowledge that there are further levels of convergence to consider (OECD 1992). At present, most contributions share the underlying assumption that convergence follows an idealized sequential process (Bröring and Leker, 2007, Hacklin et al. 2009, Curran et al. 2010, Kim et al. 2015). While authors including Curran, Bröring and Leker (2010) use

science, technology, market and industry convergence, Hacklin, Marxt and Fahrni (2010) coined knowledge, technological, applicational and industrial convergence. Integrating both streams, this paper conceptualizes the process of convergence starting with converging scientific or knowledge fields to technologies and markets or applications finally leading to industry convergence (Curran, et al. 2010, Hacklin et al. 2010).

The initial step of science convergence implies that hitherto unrelated scientific disciplines begin to cite each other in interaction with first collaborations of distinct scientific disciplines. Hence, the convergence process starts with a decreasing distance between formerly separate scientific or knowledge fields manifesting in cross-disciplinary scientific research. The next step is technology convergence, characterized by an increasing overlap of formerly independent and unrelated technological fields. The following step comprises the convergence of hitherto separate markets or fields of application, leading to new product-market combinations, which materializes in the form of convergent products. Industry convergence, as the emergence of a new sub-segment, completes the process of convergence, also reflected by a converging governance structure e.g. standards and regulations for convergent products. In addition, convergence can be distinguished by its origin i.e. supply (science and technology driven) and demand-side (market driven) convergence (Bröring 2005, Choi and Valinkangas, 2001, Stieglitz 2003, Pennings and Punaram 2001).

The convergence of formerly distinct scientific disciplines, related technological fields, regulatory frameworks or entire industries has a direct impact on universities and other research institutions, firms (particularly in research-intensive high-tech sectors) as well as policy makers (Lee 2007, Hacklin 2008, Giachetti and Battista Dagnino 2017). Since the combination of new knowledge and new technologies are required in converging industries, firms may face severe competency gaps and path dependencies, given competences are industry specific and evolve slowly (Fai and von Tunzelmann 2001, Sorensen et al. 2006). Thus, none of the involved actors in a setting of convergence has all the scientific, technological and market-related knowledge to compete successfully in a setting of convergence (Bröring, 2005; Karvonen and Kässi 2013). The usage of (new) knowledge as well as the collaboration with (or even the acquisition of) technological gatekeepers to overcome competency gaps and path dependency therefore becomes particularly relevant (Bröring 2010, Hacklin et al. 2013). Hence, convergence is currently seen as one of the most important influence factors on and trigger for developing innovation strategies, which increasingly happens at the intersection as well as recombination of previously separated fields of knowledge and technology (Carnabuci and Operti 2013, Bonnet and Yip 2009). Knowledge recombination, conceptualized as the integration of knowledge from different disciplines (Gruber et al. 2013) is a process enabling and building the foundations of technology convergence as it allows to benefit from the newly combined and subsequently integrated areas of hitherto distant areas of knowledge (Fleming and Sorenson, 2001, Gruber et al., 2013, Sorenson et al., 2006).

Against this backdrop, the concept of convergence in this study is inclusive of technology and industry fusion as well as knowledge recombination. Convergence is viewed as a process from science and technology to market and industry convergence, including all fields of application (see Figure 1). This processual view encompasses the question of how convergence evolves over time and which drivers foster the evolution of convergence. These dynamic patterns, based on the levels of convergence (science, technology, market, industry), allow for the identification of convergence movements at a very early point in time, i.e. the anticipation of convergence. Being informed early on about potential convergence processes and the numerous challenges arising in such a scenario allows companies to develop suitable strategic reactions. As the convergence process unfolds, convergent products evolve at the interface between two formerly distinct markets and industries, before culminating in the emergence of a new industry segment.

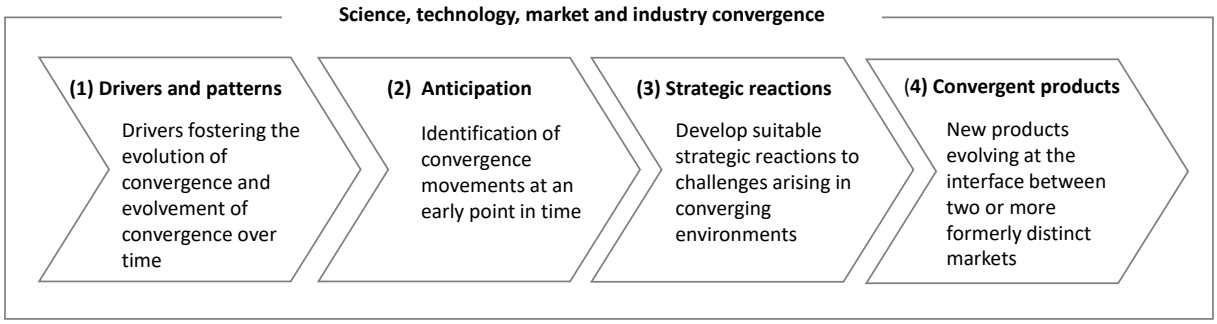


Figure 1 Processual conceptualization of convergence (based on Bröring 2005).

3. Systematic literature review

In order to start mapping the research landscape of the emerging field of convergence, we conduct a systematic literature review (SLR) of TIM-related peer reviewed studies in the domain of convergence. The main objective of an SLR is to provide an overview as complete as possible on all the published studies relating to a particular area (Littell et al. 2008, Petticrew and Roberts, 2006). This includes defining new research questions by identifying the inconsistencies in a body of knowledge, while simultaneously creating a greater understanding of the area of analysis (Cronin et al., 2008). More precisely, the purpose of a systematic literature review is to assess the current state of knowledge, identify what is unknown and contribute to advancing theory (Auger et al. 2008, Okoli and Schabram 2010). For this purpose, we systematically analyze convergence literature in four consecutive steps (see Table 1).

Table 1 Search terms and systematic literature review.

Step	*Search terms / selection criteria*	*Number of documents*
1. Database search	Databases: Scopus and Web of Science Core Collection Search terms applied to title, abstract and keywords: "scien* convergence" OR "knowledge convergence" OR "technolog* convergence" OR "industr* convergence" OR "market convergence" OR "application* convergence" OR "converg* product*" OR ("hybrid product" AND converg*) OR "converging industr*" OR "industr* fusion" OR "technolog* fusion" OR "knowledge recombination" Document types: articles and reviews Disciplines: business, management and economics Years: available before 1.1.2020	395
2. Article screening	Inclusion criteria: convergence research in TIM context	120
3. Coding	Publication information (authors, title, year, source, keywords) (i) Key issues explored (ii) Theory lens/approach (iii) Research design (iv) Convergence step (v) Convergence setting	
4. Synthesis	Identification and analysis of strands in convergence research	

The keywords in step 1 include the types of convergence, considering varying connotations used by different authors. Based on the aforementioned definition of convergence for the scope of this paper (refer to Section 2), the search term encompasses technology and industry fusion, the different steps of the convergence process as well as knowledge recombination.

The search string is applied to two well-known multidisciplinary databases, i.e. Web of Science and Scopus, to screen the title, abstracts and keywords of journal articles and reviews. The search is further limited to business, management and economics as the aim of the study at hand is to identify and analyze the status quo of the convergence research landscape within this context. The search was conducted in January 2020 and included all articles published by the end of the year 2019. After integrating results from both databases and removing duplicates, we arrive at a dataset of 395 articles.

Next, inclusion criteria for selecting the publications that will compose the final set are identified and applied in step 2. Based on the definition of the TIM field in Section 1, only articles that deal with convergence in a TIM context are included. For example, in the economics field, convergence is frequently used in a different meaning, discussing converging labor markets, interest rates or prices. In addition, articles that only address convergence as a marginal condition or context are excluded as well, since the aim of our study is to give an overview of the core field of convergence research. After a careful independent review conducted by both authors, the final sample includes 120 articles representing the convergence research landscape from a TIM perspective.

Subsequently, step 3 entails a coding procedure for a detailed analysis of the articles. First, publication information such as author(s), title, publication year, source and keywords are extracted. The key issues explored in every article are also summarized at this stage. Next, theoretical lenses or approaches are extracted and structured information on research design is collected. This includes the type of research, i.e. empirical or conceptual, and the type of data used. If the research was empirical, the research method, i.e. case study, survey, expert interviews, patent analysis etc., was also recorded. Of particular relevance in assessing convergence research is the step of the convergence process (see Figure 1), i.e. science, technology, market or industry convergence, as well as the field of convergence, e.g. ICT, nanotechnology or mechatronics, thus also taken into consideration.

The objective of the final step is to aggregate, discuss, organize and compare findings in order to make comprehensive sense out of a large number of studies. In order to help with this, Cronin et al. (2008) suggest dividing the literature into themes or categories and comparing the similarities and differences between them. This allows for the inclusion of different types of research. Thus, in this fourth step we identify and analyze different strands of literature in convergence research and deduce avenues for further research. The articles are analyzed along the criteria identified in step 3. The strands were derived using a conceptual approach, based on the processual definition of the convergence phenomenon presented in Section 2.

4. The convergence research landscape

After Rosenberg's seminal insights in 1963, research on convergence in a TIM context was only taken up again in 1985 and has gained momentum since the end of the 1990s with the advent of the so-called digital convergence. Publication activities started to intensify in 2009, reaching a maximum of 14 articles per year in 2015 (see Figure 2). This is due to the diffusion of the notion of convergence beyond the classical ICT setting, becoming a mega-trend for multiple sectors of the economy.

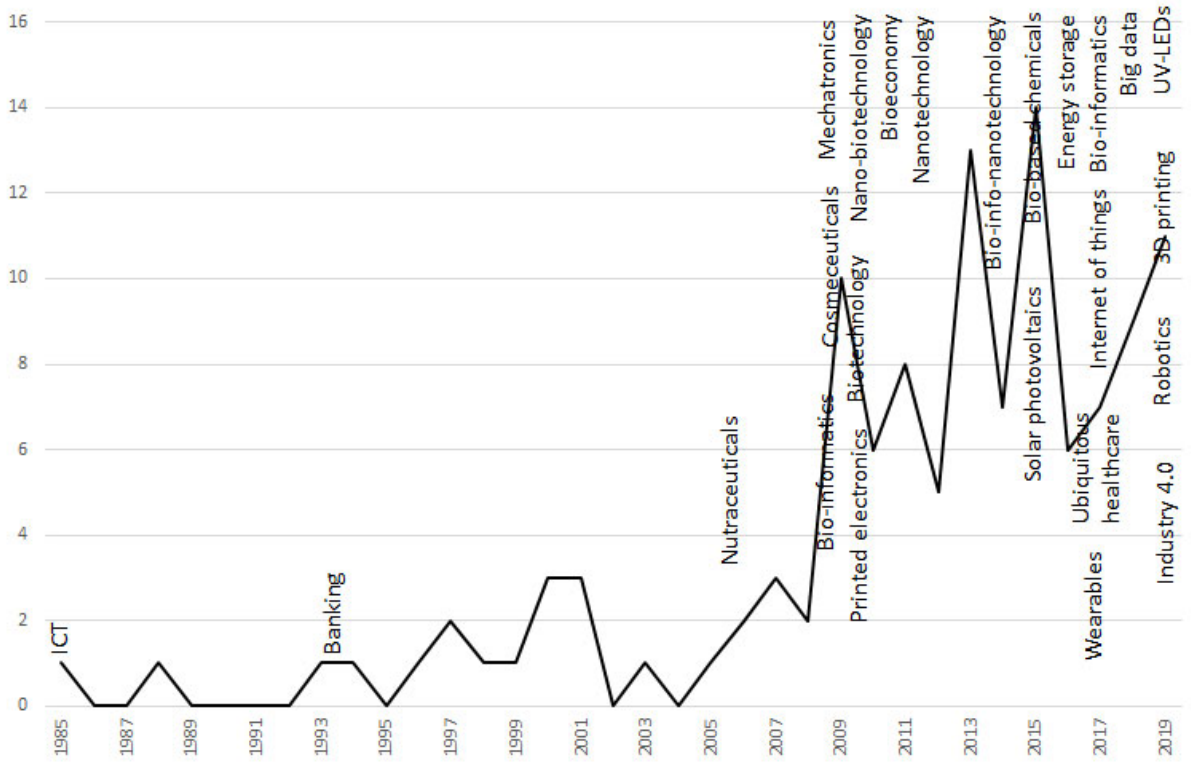


Figure 2 Timeline of publications dealing with convergence in a TIM context and the fields of convergence by first appearance.

Source: Data derived from Scopus and Web of Science.

An overview on the main outlets for convergence research is presented in Table 2. Technological Forecasting and Social Change is the leading journal in this field with 21 articles, most of them published within the last five years. After a substantial gap, Technovation follows with eight articles. The International Journal of Innovation and Technology Management with seven articles is closely linked with the Portland International Society for Management of Engineering and Technology (PICMET) Conference, which regularly features a track on convergence research. The International Journal of Technology Management, Research Policy and Technology Analysis and Strategic Management follow in close succession with six articles each. The unambiguous classification of most of the journals to the TIM domain demonstrates the successful anchoring of convergence research in this particular field of management literature (Linton and Thongpapanl 2004).

Table 2 Journals with five or more publications on convergence research.

Journal	*No. of publications*
Technological Forecasting and Social Change	21
Technovation	8
International Journal of Innovation and Technology Management	7
International Journal of Technology Management	6
Research Policy	6
Technology Analysis and Strategic Management	6

Source: Data derived from Scopus and Web of Science.

Based on the main topics covered in each article, four strands of literature in convergence research are identified based on the processual perspective on convergence as depicted in Figure 1 (see Section 2). The patterns of convergence, i.e. how a process of convergence evolves over time and which drivers foster the evolution of convergence, is pivotal in convergence research and thus covered by the first strand of literature (strand no.1). This strand focuses on the phenomenon of convergence itself. Based on these insights, possible convergence movements can be identified at a very early point in time, i.e. the anticipation of convergence (strand no.2). Anticipation of convergence thus allows for suitable strategic reactions to convergence, i.e. how companies deal with the numerous challenges arising in a setting of convergence (strand no.3). As converging industries not only require new strategic approaches, but also materialize at the product level, we identify those convergent products evolving at the interface between two formerly distinct markets and industries as strand no.4.

Strand No. 1: Drivers and patterns of convergence

Key issues explored, theory lens/approach and research design

The body of research on 'Drivers and patterns of convergence' is the second largest strand with 39 articles (33%), starting as early as 1985 until 2019 (Table 3). The fact that one-third of all convergence research articles focuses on questions revolving around the drivers of convergence, the patterns in how convergence unfolds as well as different types of convergence confirms the still evolving nature of convergence research.

Although the drivers of convergence have been categorized in different ways (e.g. Song et al. 2017, Curran 2013), an overarching scheme appears. Drawing on the classical framework of technology push and market pull (Martin 1994) and its extension to include regulation as regulatory push/pull (Rennings 2000), convergence can be driven by market pull, technology push or regulatory push/pull or a combination of these. Based on Malhotra and Gupta (2001), Bröring (2005) adopts these three themes to the convergence realm. Convergence can thus be driven by technological change (e.g. Appio et al. 2017, Caviggioli 2016), market needs (e.g. Schmidt et al. 2016) or emerging standards and regulation (e.g. Han and Sohn 2016). In addition to reflecting on the drivers of convergence, it seems important to note that convergence in the three areas of technology, market and regulation in most cases seems to present an interwoven development, but as Garmbardella and Torrisi (1998) reveal, can also occur separately.

Although (de)regulation, together with technological change and market demand, is an important driving force of convergence, only two articles on policy and regulation in convergence settings were published after 2004. One possible explanation could be the predominance of technological drivers for convergence processes with the rise of digital technologies in the turn of the new millennium. Technological progress, particularly in the realm of ICT, is often mentioned as one of the main sources to start and feed convergence processes, e.g. the internet of things or ubiquitous healthcare (Kim et al. 2017). Moreover, regulation issues are likely to be covered as side aspects or contextual elements within studies focusing on other aspects of convergence. For example, Kim et al. (2017) find that standards are a driver for convergence, while their study also highlights the interplay between standards and the emergence of technological trajectories in a convergence setting.

This strand also discusses the types of convergence, which appear to be crucial in determining the nature and implications of convergence. In this regard, Greenstein and Khanna (1997) coin the distinction between convergence in substitutes, i.e. two different product classes start to share features that will make them interchangeable for customers, and convergence in complements, i.e. two product classes are complemented by a novel third class (see also Lei 2000). This reasoning has been further expanded to the industry level where, in a case of complementary convergence, the new

sub-segment emerges in addition to the formerly distinct industry segments and thus entails changes and shifts to the existing industry landscape. In a case of substitutive convergence, however, the new sub-segment replaces the former industry segments and thus triggers more severe consequences for the involved actors in the established industry segments (Bröring 2010). In a similar vein, Kim et al. (2015) make a distinction between inter- and intra-industry convergence and introduce an industry convergence index based on an analysis of unstructured data.

When diving into the theoretical foundations behind the drivers and patterns of convergence, there appears to be a lack (and variety) of connection to previous literature which contributes significantly towards explaining the missing conceptual clarity in convergence research. Most strikingly, about 25% of the research uncovering the phenomenon of convergence does not show firm ties to any theoretical foundation. In fact, at most, such research appears to review the literature on convergence as a concept rather than providing a theoretical foundation and a theory lens to understand and explain the phenomenon more profoundly. As depicted in Table 3, the remainder of the research is rooted in a variety of theoretical perspectives. An important theoretical reservoir is strategic management, drawing on different aspects such as the resource-based view (RBV) and its related concepts such as absorptive capacity and core competences (Penrose 1959, Wernerfeldt 1984, Barney 1991). Another source of theoretical knowledge revolves around evolutionary economics, mainly technological change, regimes and trajectories (Nelson and Winter 1982). Studies primarily concerned with method development are based on informetrics such as link prediction (Aaldering et al. 2019), citation analysis (Caviggioli 2016) or taxonomies (Geum et al. 2016). Although informetrics would not be considered as a classic theoretical foundation in a management context, the amount of method development in convergence research prompted us to include informetrics as a separate perspective.

The missing conceptual clarity is also reflected in the research design where, apart from six mostly earlier conceptual papers (Malerba 1985, Graham 1993, Messerschmitt 1996, Andergassen et al. 2006, Haas and Ham 2015, Bresnahan 2019), the remainder of the work is based on empirical studies. Predominantly quantitative approaches based on patent data are used to identify and assess convergence while qualitative approaches are limited to case studies and interviews.

Convergence steps and settings

This narrow approach to research design aligns well with technology convergence being the dominant perspective of 70% of the studies, while science, market and industry convergence are the main lens of 10% of the studies, respectively. Hence, technology convergence has been studied from different angles to unpack the phenomenon. A considerable number of studies analyzes the drivers of technology convergence (e.g. Littler and Coombs 1988, Jeong 2014, Caviggioli 2016 or Kim et al. 2017). Further aspects include the identification (e.g. You et al. 2014 or Niemann et al. 2013), the degree (e.g. No and Park 2010 or Eilers et al. 2019) and the dynamics of technology convergence (e.g. Yun and Geum 2019 or Karvonen et al. 2012). While technology convergence has been consistently addressed since 1985, the earliest studies on the patterns of science, market and industry convergence were published only in 2011 and 2015 (see Haas and Ham 2015, Thanassoulis 2011, Kim et al. 2015 respectively). The majority of studies on science convergence identify drivers, whereas authors tackling industry convergence focus on identification and degree of industry convergence. Market convergence is addressed from the drivers as well as the identification perspective, although both are in an embryonic state.

The variety of convergence fields demonstrates that convergence research has moved well beyond ICT and starts to encompass recently emerged fields such as the internet of things. Notwithstanding eight articles with a particular focus on ICT, many studies tackle other possible fields of convergence such as the bioeconomy and biotechnology (Aaldering et al. 2019, Golembiewski et al. 2015, Aminullah et al.

346 2015), energy storage (Sick et al. 2019, Jeong et al. 2016), health care (Yun and Geum 2019), internet
347 of things (Kim et al. 2017), logistics (Niemann et al. 2013), nanotechnology (You et al. 2014), or printed
348 electronics (Karvonen et al. 2012). Moreover, a variety of articles examines patterns of convergence
349 across industries as an attempt to broaden the often-narrow view in this strand of research (e.g. Heo
350 and Lee 2019, Moaniba et al. 2018, Kim et al. 2015).

351 **Table 3** Strand 1: Extant studies focusing on drivers and patterns of convergence.

Article	*Key issues explored*	*Theory lens/ approach*	*Research design*	*Convergence setting*	*Step*	*AAC*
Aaldering, Leker, Song (2019)	Tendencies of the biotechnology industry to converge with adjacent market segments	Informetrics (link prediction)	Quantitative (collaborations)	Biotechnology	MC	0.0
Bresnahan (2019)	Differences between supply and demand side convergence	n/a	Conceptual	ICT	TC	1.0
Eilers et al. (2019)	Identifying one-way or two way technology convergence	StratMgmt (weak signals)	Quantitative (patents)	UV-LEDs	TC	1.0
Heo, Lee (2019)	Measurement and dynamics of inter-industry convergence	n/a (convergence)	Quantitative (input output tables)	Various	IC	0.0
Sick et al. (2019)	Stages and types of industry convergence	StratMgmt (absorptive capacity)	Quantitative (collaborations)	Energy storage	IC	2.0
Yun, Geum (2019)	Index-based approach to measure dynamics of technological convergence	Informetrics (trend analysis)	Quantitative (patents)	Health care	TC	0.0
Jeong, Lee, Cho (2018)	Relationships among IJR (international joint research) network, knowledge diffusion and science convergence	StratMgmt (knowledge diffusion)	Quantitative (publications)	Energy storage	SC	0.0
Moaniba, Su, Lee (2018)	Relationship between cross-disciplinary knowledge and the technological value of an invention	StratMgmt (RBV)	Quantitative (patents)	Various	SC, TC	1.0
Appio, Martini, Fantoni (2017)	Scientific and technological diversity as driver of impactful inventions	StratMgmt (KBV, KR)	Quantitative (patents)	Bioinformatics	SC, TC	2.0
Kim, Lee, Kwak (2017)	Standards as and technological trajectories in convergence	EE (technological change)	Quantitative (patents)	Internet of things	TC	3.3
Su, Moaniba (2017)	Evolving of conventional technologies into interdisciplinary technologies	n/a (interdisciplinarity)	Quantitative (patents)	Various	TC	3.3
Caviggioli (2016)	Relevance of technology level drivers of new technology fusions	Informetrics (citations)	Quantitative (patents)	Various	TC	8.5
Geum, Kim, Lee (2016)	Taxonomy for industry convergence	n/a (convergence)	Quantitative (case studies, cluster analysis)	Various	IC	0.8
Han, Sohn (2016)	Technological convergence in standards related to ICT	Informetrics (association rule)	Quantitative (patents)	ICT	TC	4.8
Jeong et al. (2016)	Relationships among IJR (international joint research) network, knowledge	StratMgmt (knowledge diffusion)	Quantitative (bibliometrics)	Lithium ion battery, fuel	SC	0.5

	diffusion and science convergence			cell and wind power		
Schmidt, Makadok, Keil (2016)	The effect of customer-specific synergies on market convergence	StratMgmt (customer-specific synergies)	Quantitative (firm model)	Various	MC	3.3
Aminullah et al. (2015)	Find triggers, drivers and enabling factors of technological convergence	StratMgmt (RBV)	Qualitative (case study)	Bio-based chemicals	TC	0.6
Golembiewski, Sick, Bröring (2015)	Value chain shifts due to convergence	StratMgmt (value chain)	Quantitative (patents)	Bioeconomy	TC	1.6
Haas, Ham (2015)	Relevance of peripheral knowledge for breakthrough innovation	StratMgmt (KBV, KR)	Conceptual	Various	SC	2.0
Jeong, Lee (2015)	The influence of technological and resource allocation contexts on technology convergence	StratMgmt (KBV, KR)	Quantitative (patents)	Various	TC	1.8
Kim et al. (2015)	Inter and intra industry convergence	StratMgmt (AC, cognitive distance)	Quantitative (publications)	Various	IC	7.6
Nakamura et al. (2015)	Identify technological sub-domains to be combined between two industries	StratMgmt (KBV, KR)	Quantitative (patents)	Automobile, aircraft	TC	7.2
Kodama (2014)	Technology-service convergence	n/a	Qualitative (case study)	Personal computer, automobile	TC	2.3
Jeong (2014)	Actors of the triple helix driving technology convergence	OrgScience (strategic collaboration)	Quantitative (patents)	Various	TC	1.0
You, Kim, Jeong (2014)	Measurement of technology and market convergence	n/a (convergence)	Quantitative (patents)	Nano biosensor sector	TC	0.8
Niemann, Moehrle, Walter (2013)	Business method patents to measure technology convergence	Informetrics (business method patents)	Quantitative (patents)	Logistics industry	TC	0.7
Protogerou, Caloghirou, Siokas (2013)	Structure and dynamics in technology collaboration networks	StratMgmt (network theory)	Qualitative (SNA)	ICT	SC	1.7
Karvonen, Lehtovaara, Kässi (2012)	Analyze the dynamics between traditional and emerging industries in a setting of convergence	EE (technological trajectories)	Mixed method approach (patents and interviews)	Paper & electronics (RFID)	TC	1.4
Thanassoulis (2011)	Valuation of convergence for consumers	Marketing (product bundling)	Quantitative (econometric model)	ICT; media	MC	0.7
No, Park (2010)	Degree and trajectories of technology fusion	Informetrics (taxonomies)	Quantitative (patents)	Nano-biotechnology	TC	7.7
Freddi, D. (2009)	Evolution of technology fusion in low- and medium-tech sectors	EE (technological change)	Mixed methods (interviews and case studies)	Mechatronics	TC	3.0
Malanowski, Compaó (2007)	Opportunities and risks resulting from converging applications	EE (technological trajectories)	Qualitative (interviews)	ICT	TC	0.2

Andergassen, Nardini, Ricottilli (2006)	Innovation and imitation as antecedents of technology convergence	StratMgmt (AC)	Conceptual	General	TC	1.4
Athreye, Keeble (2000)	Technological convergence as a factor determining sectoral ownership patterns	n/a (convergence)	Quantitative (SIC codes, survey)	ICT	TC	1.7
Gambardella, Torrisi (1998)	Does technology convergence lead automatically to market convergence?	StratMgmt (RBV, core competences)	Quantitative (patents, collaborations)	ICT	TC	10.5
Athreye (1997)	Technological convergence as historical occurrence when markets in technological knowledge emerge	EE (technological change)	Qualitative (case study)	General	TC	0.4
Messerschmitt (1996)	Opportunities and challenges of ICT convergence	n/a	Conceptual	ICT	TC	0.1
Graham (1993)	Opportunities and challenges of ICT convergence	n/a	Conceptual	ICT	TC	0.2
Littler, Coombs (1988)	Influence of R&D funding on technology convergence	n/a	Qualitative (interviews)	Various	TC	0.0
Malerba (1985)	Effects of the structure of demand on the rate and direction of technological change	EE (technological regimes)	Conceptual	Semicon-ductor	TC	0.4

Notes: StratMgmt=strategic management, EE=evolutionary economics, RBV=resource-based view, KR=knowledge recombination, AC=absorptive capacity, SC=science convergence, TC=technology convergence, MC=market convergence, IC=industry convergence, AAC=average annual citation

Strand No 2: Anticipation of convergence

Key issues explored, theory lens/approach and research design

'Anticipation of convergence' comprises 24 papers or 20% of the sample (Table 4). The articles were published between 2008 and 2019, indicating an emerging strand of convergence research. Anticipation in most cases draws upon the logic of convergence as a process, using earlier stages such as science, technology and market convergence to anticipate industry convergence. Articles in this strand pursue two objectives in parallel, the development of new methods to anticipate convergence and the identification of emerging fields of convergence.

Looking at the overall theoretical lens used, it becomes evident that, again, a considerable number of studies lacks solid theoretical underpinning, only referring to particular concepts such as convergence itself, emerging technologies, disruptive innovation or technology roadmapping. However, the majority of research in the context of anticipation of convergence revolves around method development and is firmly built on informetrics. While citations prevail in earlier contributions, more recent work includes topic modeling (Lee et al. 2016), link prediction (Kwon et al. 2019) and other techniques as an expression of the possibilities provided by digital technologies (e.g. Kose and Sakata 2019). A few remaining studies are rooted in strategic management, relying on the concept of weak signals (Kwon et al. 2018, Song et al. 2017).

Given this methodological lens, it is hardly surprising that this strand is dominated by empirical contributions, with only four conceptual articles. Method development is based on indicators for the steps of the convergence process. Scientific publications are predominantly used as indicators for

science convergence, such as (co)authorships, (co)citations and keyword analyses (Kose and Sakata 2019, Ruiz-Navas, Miyazaki 2018). Recently, Kim et al. (2019) added Wikipedia hyperlinks to detect converging fields of knowledge. Technology convergence is indicated using patent analysis based on (co)citations (Karvonen and Kaessi 2013), IPC co-classification (Kwon et al. 2019, Song et al. 2017, Gauch and Blind 2015) as well as semantics (Venugopalan and Rai 2015, Su and Sohn 2015, Preschitschek et al. 2013). These quantitative approaches are complemented by a few qualitative attempts, e.g. using roadmapping (Yasunaga et al. 2009) and historical case studies (Schnars et al. 2008). Indicators for market convergence include new product launches of convergent products, keyword network analysis of products and services, and customer trends (Bornkessel et al. 2014, Kwon et al. 2018, Ho and Chen 2009). Interestingly, these indicators are most often developed in isolation for each step, hardly ever linking the steps of the convergence process. Moreover, the time lags between science, technology, market and industry convergence have yet to be addressed in detail. There is only evidence for a sequential approach regarding the development of science (proxies are publications) and technologies (patents) (see Curran et al. 2010).

Convergence steps and settings

Very similar to the previous strand, technology convergence is the dominant perspective in about 70% of the studies. Science convergence, as the first step of the convergence process, is used in about 20% of the articles, while market convergence accounts for about 10%. The present focus on the step of technological convergence may be seen in the fact that patents as indicators are rich in information, well-structured and publicly available, allowing for a less complex and clearer cut than in the case of science or market convergence (Curran 2013). However, novel approaches such as link prediction are on the rise to access unstructured data, as e.g. studies by Kim et al. (2019) indicate.

Interestingly, the research settings do not reveal a clear focus on ICT, but rather a wide range of industries such as bioinformatics (Yasunaga et al. 2009), healthcare (Eidam et al. 2017), nutraceuticals (Bornkessel et al. 2014), and printed electronics (Karvonen and Kässi 2013). Recent publications in 2018 and 2019 reflect the influence of digitization by adding 3D printing (Wang et al. 2019), big data (Ruiz-Navas and Miyazaki 2018) and robotics (Kose and Sakata 2019). ICT as an established field of convergence is used as a reference to validate new approaches to anticipate convergence.

Table 4 Strand 2: Extant studies focusing on anticipation of convergence.

Article	*Key issues explored*	*Theory lens/approach*	*Research design*	*Convergence setting*	*Step*	*AAC*
Kim, Kim, Lee (2019)	Anticipation of technology convergence based on Wikipedia hyperlinks	Informetrics (link prediction)	Quantitative (Wikipedia hyperlinks)	3D printing	SC, TC	5.0
Kose, Sakata (2019)	Anticipating of technology convergence based on publication citation analysis	Informetrics (networks, clusters, similarity)	Quantitative (publications)	Robotics	SC, TC	2.0
Kwon et al. (2019)	Technology-driven industry convergence	Informetrics (link prediction)	Quantitative (patents)	Various	TC	0.0
Wang et al. (2019)	Identification of emergent topics in a field of technology convergence	n/a (emerging technologies)	Quantitative (patents)	3D printing	TC	2.0
Kwon et al. (2018)	Weak signal detection of inter-industry convergence	StratMgmt (weak signals)	Quantitative (keywords)	Various	MC	0.0
Ruiz-Navas, Miyazaki (2018)	Keywords as a proxy of knowledge convergence	Informetrics (keywords)	Quantitative (publications)	Big data	SC	0.0

Eidam et al. (2017)	Publication and patent analysis to anticipate industry convergence in ubiquitous healthcare	n/a (convergence)	Quantitative (patents)	Healthcare	SC, TC	0.3
Song, Elvers, Leker (2017)	New approach based on knowledge flows to anticipate technology convergence	StratMgmt (weak signals)	Quantitative (patents)	Nutraceuticals, Nano-technology, Wearables	TC	6.3
Lee, Han, Sohn (2016)	Predict technological convergence patterns	Informetrics (topic modelling)	Quantitative (patents)	General	TC	4.8
Venugopalan, Rai (2015)	Semantic patent classification to identify technology convergence	Informetrics (topic modelling)	Quantitative (patents)	Solar photo-voltaic	TC	7.6
Gauch, Blind (2015)	Generalized method of measuring technology convergence	Informetrics (patents, standards)	Quantitative (patents)	Various	TC	5.6
Suh, Sohn (2015)	Text mining and association rules analysis to identify technology convergence	Informetrics (clustering)	Quantitative (patents)	ICT	TC	3.0
Bornkessel, Bröring, Omta (2014)	Anticipating convergence from a value chain perspective	Informetrics (various)	Quantitative (scientific publications, patents, collaborations)	Nutraceuticals	SC, TC, MC	1.5
Karvonen, Kässi (2013)	Anticipate science and technology convergence based on patent citation data	Informetrics (citations)	Quantitative (patent citations)	Printed electronics	TC	10.7
Preschitschek et al. (2013)	Semantic similarity of patents as an indicator of technology convergence	Informetrics (semantics)	Quantitative (patents)	NFF	TC	3.6
Karvonen, Kässi (2012)	Evaluate patent citation data as a method to anticipate convergence	Informetrics (citations)	Quantitative (patent citations)	Printed electronics	TC	0.1
Curran, Leker (2011)	Monitoring concept to anticipate convergence based on publicly available data	n/a (convergence)	Conceptual, Quantitative (scientific publications, patents)	Nutrac-euticals	TC	14.8
Karvonen, Kässi (2011)	External and self-citations within and beyond industry citations as an indicator for technology convergence	Informetrics (citations)	Quantitative (patent citations)	Printed electronics	TC	1.8
Lee, Lee, Yoon (2011)	Clustering technologies based on their growth patterns	Informetrics (taxonomies)	Quantitative (patents)	ICT	TC	4.0
Curran, Bröring, Leker (2010)	Anticipate industry convergence based on publicly available data	n/a (convergence)	Quantitative (scientific publications, patents)	Nutra-ceuticals	TC	8.8
Ho, Chen (2009)	Scenario analysis to anticipate convergence	n/a (disruptive innovation)	Conceptual	ICT	MC	1.3
Yasunaga, Watanabe, Korenaga (2009)	Roadmapping as a tool to promote convergence	n/a (roadmapping)	Conceptual	Bio-informatics	TC	5.8

Schnaars, Thomas, Irmak (2008)	Historical examples to anticipate convergence	n/a (convergence)	Qualitative (case studies)	Various	TC	1.0

Notes: StratMgmt=strategic management, SC=science convergence, TC=technology convergence, MC=market convergence, IC=industry convergence, AAC=average annual citation

Strand No 3: Strategic reactions to arising challenges in a setting of convergence

Key issues explored, theory lens/approach and research design

The largest strand in convergence literature with 44 articles (37%) is dedicated to 'Strategic reactions of companies to arising challenges in a setting of convergence' (Table 5). In comparison to the earliest contribution to the anticipation of convergence in 2008, this stream started much earlier in 1994. After a gap of five years until the second contribution in 1999, there has been consistent publication activity until 2019.

In line with the general importance of the resource-based view (RBV) in management (e.g. Penrose 1959; Wernerfeldt 1984, Barney 1991), most contributions connect to this eminent theoretical lens in order to elucidate firms' strategic reactions in converging environments. With respect to internal factors, the (often technological) knowledge base of a firm (as a prime resource, also relating to the knowledge-based view (Grant, 2002) as a subtheme of the RBV) is a subject of several studies (Lavarello 2016, Kim et al. 2014, Cunha 2009, Bröring and Leker 2007, Bröring et al. 2006, Bierly and Chakabarti 2001, Fujimoto et al. 2000, Lei 2000). Related aspects include organizational tensions (Achtenhagen and Raviola 2009), knowledge integration (De Boer et al. 1999) and very recently specific technology convergence capabilities (Kim et al. 2019). Further internal perspectives include the organization of innovation processes in convergence (Gandia 2013), business models (Klang and Hacklin 2013), incremental vs. radical innovation (Maine et al. 2014, Hacklin et al. 2005), entrants vs. incumbents (Hacklin et al. 2013) and product portfolios (Giachetti et al. 2017).

Studies prioritizing external factors predominantly address collaborative activities on the firm level such as strategic communities (Kodama 2018), alliances (Hsu and Prescott 2017), consortia (Allarakhia and Walsh 2012), vertical vs. horizontal collaborations (Ahn et al. 2010, Goswami, Raghavendran 2009, Harianto and Pennings 1994), networks (Lee 2007) and open innovation (Bröring 2010). These studies (although not mentioning it) implicitly draw upon the perspective of the relational view of the firm (Dyer and Singh, 1998). Further studies look at collaborations on the industry level through a value chain or supply chain lens (Carraresi et al. 2018, Karvonen and Kaessi 2010, Rim et al. 2009, Wirtz 2001). Additionally, more recent and emerging conceptional approaches used to study convergence include ecosystems (Rong et al. 2013) or open business models (Frankenberger et al. 2014).

As depicted in Table 5, strategic management is the major theoretical perspective of about two thirds of the studies in this strand. However, the depth of the theoretical foundations used in the respective contributions varies considerably, where only a few studies firmly position their research in strategic management (e.g. Maine et al. 2014, Hacklin and Wallin 2013, Bröring 2010, Lee 2007, Bierly and Chakrabarti 2001). Within the aforementioned realm of the RBV, absorptive capacity (Cohen and Levinthal, 1992), dynamic capabilities (Teece et al. 1997) and core competencies as well as combinative capabilities (Kogut and Zander 1992) and knowledge integration (Gruber et al. 2013) provide the breeding ground for the analysis of strategies to close competence gaps. A related perspective drawing on strategic renewal is rooted in organizational learning theory (Lant and Mezias 1992, Levitt and March 1988, Argyris and Schon 1978). Further theoretical insights stem from evolutionary economics (Nelson and Winter 1982).

In comparison to the previous two strands, more conceptual studies have been undertaken. The fairly high average annual citations for these articles indicate that convergence research appreciates and needs conceptual foundations (e.g. Carraresi et al. 2018, Agarwal and Brem 2015, Bores et al. 2003, DeBoer et al. 1999). Empirical studies also draw a different picture compared to the two previous strands as qualitative case study approaches prevail, as opposed to quantitative and mixed-method approaches. Quantitative approaches mainly apply patent analysis and regression (e.g. Kim et al. 2019, Hsu and Prescott 2017, Kim et al. 2014), while surveys, panel and financial data play a minor role (Benner and Ranganathan 2013, Hwang and Kim 2011, Harianto and Pennings 1994). The dominance of conceptual work and empirical case studies indicates that convergence research is still of exploratory nature and seeks to identify emerging theoretical relationships by in-depth analyses of companies' strategic reactions to convergence.

Convergence steps and settings

In fact, many of the conceptual and qualitative empirical studies investigate industry convergence, while technology convergence is covered in quantitative as well as qualitative empirical work. In this strand only, technology and industry convergence show almost equal shares with 49% and 44%, leaving very little room for science and market convergence. Bearing in mind that technology convergence is the most well-defined stage of the convergence process and the easiest to identify and analyze, the present focus on strategic reactions to technology convergence in most studies seems reasonable. Moreover, following the processual view on convergence, converging technologies are most often early predictors of blurring industry boundaries and thus the starting point to take strategic actions in order to close technology and market competence gaps.

The research setting is mainly focused on ICT, with 50% of the articles entirely or partly investigating convergence in ICT, as an ultimately substitutive convergence. As ICT is one of the few areas where the process of industry convergence has been completed, ICT is a prime area for observing strategic reactions and their consequences once sectors have converged. Other, albeit smaller, focus areas include nano- (Allarakhia and Walsh 2012) and biotechnology (Lavarello 2016, Ahn et al. 2010), the newly emerged field of nano-biotechnology (Kim et al. 2014, Maine et al. 2014) as well as the bioeconomy in a broader sense (Boehlje and Bröring 2011). More recent fields of convergence in the digital arena have only been tackled by one article on Industry 4.0 (Kim et al. 2019).

Table 5 Strand 3: Extant studies focusing on strategic reactions to arising challenges in a setting of convergence.

Article	*Key issues explored*	*Theory lens/ approach*	*Research design*	*Convergence setting*	*Step*	*AAC*
Kim, Jung, Hwang (2019)	Measuring firm-level technology convergence (TC) capability	StratMgmt (RBV)	Quantitative (patents)	Industry 4.0	TC	2.0
Carraresi, Berg, Bröring (2018)	Emergence of inter-industry value chains in converging environments	StratMgmt (value chain)	Qualitative (case study)	Bioeconomy	IC	4.5
Kodama (2018)	Strategic communities to facilitate knowledge convergence	StratMgmt (RBV)	Qualitative (case study)	ICT	SC	0.0
Hsu, Prescott (2017)	Why and when do firms acquire knowledge through learning from alliances, semi-convergence	OrgScience (learning theory)	Quantitative (regression)	ICT	IC	0.0
Giachetti, Battista Dagnino (2017)	How technological convergence in a product category shapes firm strategy	Information economics, organizational	Quantitative (regression)	ICT	TC	1.7

		theory (theory of imitation)				
Lavarello (2016)	How firms respond to the increasing complexity of their knowledge bases	EE (path dependency, diversification)	Quantitative (patents)	Biotechnology	TC	0.0
Agarwal, Brem (2015)	Stages of convergence-related business transformation	StratMgmt (business transformation)	Qualitative (case study)	ICT	TC	5.6
Frankenberger, Weiblen, Gassmann (2014)	Open business models	StratMgmt (business models)	Qualitative (case study)	Various	IC	4.5
Kim et al. (2014)	Firms' core technological domains and competitive intensity	n/a (convergence)	Quantitative (patents)	Bio-info-nanotechnology	TC	0.7
Maine, Thomas, Utterback (2014)	Radical innovations	StratMgmt (RBV, opportunity recognition, DC, network theory) EE (Path dependency, technological change)	Qualitative (case study)	Nano-biotechnology	TC	5.7
Benner, Ranganathan (2013)	The influence of analysts on product market strategies	Institutional theory (investor expectations)	Quantitative (panel data)	ICT	IC	3.4
Gandia (2013)	Strategic organisation of innovation processes	StratMgmt (strategic choices)	Qualitative (case study)	Videogames & animation	IC	1.3
Hacklin, Battistini, Von Krogh (2013)	Strategic pathways in converging industries	StratMgmt (strategic choices)	Qualitative (case study)	Various	IC	4.4
Hacklin, Wallin (2013)	Integration of specialized and interdisciplinary knowledge	OrgScience (knowledge management	Qualitative (literature review)	Various	TC	6.6
Klang, Hacklin (2013)	Business model changes in technology convergence	StratMgmt (business models)	Qualitative (case study)	ICT	TC	0.7
Rikkiev, Mäkinen (2013)	Collaboration success factors for different types of technology convergence	StratMgmt (RBV, KBV)	Mixed methods (case study)	ICT	TC	0.7
Rong, Shi, Yu (2013)	Business ecosystems for the development of emerging industries	StratMgmt (platform strategies)	Qualitative (case study)	ICT	IC	2.6
Allarakhia, Walsh (2012)	Model to manage nanotech concortia	n/a	Qualitative (case study)	Nanotechnology	TC	3.9
Bengtsson, Johansson (2011)	Market regimes	StratMgmt (competitive strategy)	Qualitative (case study)	ICT	MC	1.0
Boehlje, Bröring (2011)	Innovation dilemmas in convergence	StratMgmt (innovation adoption)	Conceptual	Bioeconomy	IC	3.2
Hwang, Kim (2011)	Successful innovation in a setting of technology convergence	n/a	Quantitative (survey)	ICT	TC	0.4
Lamberti, Lettieri (2011)	Legitimation strategies	StratMgmt (legitimacy)	Qualitative (case study)	Nutraceuticals	IC	1.8

Ahn, York, Rizova (2010)	Vertical vs. horizontal relationships to shape technology convergence and commercialisation pathways	StratMgmt (network theory)	Qualitative (case study)	Biotechnology	TC	0.9
Bröring (2010)	Innovation strategies to adress new industry segments	StratMgmt (RBV)	Qualitative (case study)	ICT; Chemistry & Printing; Nutraceuticals	IC	3.2
Hacklin, Marxt, Fahrni (2010)	Stages of the convergence process	EE (industry evolution)	Qualitative (case study)	ICT	TC	2.2
Karvonen, Kässi, Kapoor (2010)	Innovation strategies	EE (industry evolution, technological trajectories)	Quantitative (patents, financial and market data)	Paper & electronics (RFID)	TC	0.7
Achtenhagen, Raviola (2010)	Organizational tensions in technology convergence	OrgScience (org. tensions)	Qualitative (case study)	Media	TC	3.5
Cunha (2009)	Effects of Internal resources on service innovation	StratMgmt (RBV)	Conceptual	ICT	IC	0.5
Goswami, Raghavendran (2009)	Partnering models in mobile banking	n/a	Conceptual	Banking	IC	1.4
Jang (2009)	Technological convergence through industrial research	Economics (market failure)	Quantitative (research collaboratio ns)	Various	TC	0.5
Rim, Han, Sawng (2009)	Converging supply chains	StratMgmt (business models)	Conceptual	ICT	IC	0.5
Bröring, Leker (2007)	Firms' engagement in innovation	StratMgmt (RBV)	Empirical	Nutraceuticals	IC	3.0
Lee (2007)	Market entry strategies	StratMgmt (network theory, market entry)	Quantitative (panel data)	ICT	IC	6.8
Bröring, Cloutier, Leker (2006)	Front end of innovation in converging industries	StratMgmt (RBV)	Qualitative (case study)	Nutraceuticals	IC	7.4
Hacklin, Raurich, Marxt (2005)	Disruptive innovation	StratMgmt (RBV)	Qualitative (case study)	ICT	TC	1.3
Borés, Saurina, Torres (2003)	Economic determinants of firm strategies	n/a	Conceptual	ICT	TC	5.6
Bierly, Chakrabarti (2001)	Dynamic knowledge strategy	StratMgmt (RBV, KBV)	Conceptual	ICT	IC	1.1
Andersson, Mölleryd (2001)	Increased mobility in organizations due to technology convergence	StratMgmt (network theory)	Qualitative (interviews)	ICT	TC	0.1
Wirtz (2001)	Reconfiguring value chains in converging markets	StratMgmt (value chain)	Qualitative (case study)	ICT; media; communicatio ns	MC	4.8
Fujimoto, Miyazaki, Von Tunzelmann (2000)	Technological knowledge of firms in converging environments	Informetrics (multidimension al scaling)	Quantitative (publication s and patents)	Telemedicine	SC, TC	0.5
Lei (2000)	Impact of technology convergence on industry	StratMgmt (RBV)	Qualitative (case study)	ICT; Semiconducto r	TC	4.2

	structure and firm competences					
De Boer, Van Den Bosch, Volberda (1999)	Organizational knowledge integration	StratMgmt (RBV)	Qualitative (case study)	ICT; media	IC	7.4
Lei (1997)	Competence building in a context of convergence	StratMgmt (RBV)	n/a	n/a	TC	2.0
Harianto, Pennings (1994)	How organizations are drawn into converging technological developments	StratMgmt (KBV)	Quantitative (financial data)	Banking	TC	0.7

Notes: StratMgmt=strategic management, RBV=resource-based view, KBV=knowledge-based view, KR=knowledge recombination, AC=absorptive capacity, EE=evolutionary economics, OrgScience=organization science, SC=science convergence, TC=technology convergence, MC=market convergence, IC=industry convergence, AAC=average annual citation

Strand No 4: Convergent products arising at the borderline of different industries

Key issues explored, theory lens/approach and research design

Studies on the emergence of convergent products builds the smallest but growing group of literature with a share of 13 articles (11%) (Table 6). Moreover, the terminology used to describe such products is far from a common understanding as it encompasses terms such as converged, convergent or convergence products, hybrid products or borderline products. These all share the idea that product functionalities from hitherto distinct product categories are merged into one product (Han et al. 2009). In particular, attention has been paid to the inherently ambiguous nature of convergent products arising from the integration of features and functionalities from different product categories (Han et al 2018). These studies have been published between 2009 and 2018, thus, present a rather young and emergent strand within the landscape of convergence literature.

This strand is mostly product and consumer focused, with ten studies applying this lens, while only three studies take a firm perspective. The three studies at the firm-level present success factors for firms to develop convergent products. Lee et al. (2013) identified explorative and exploitative learning and vertical collaboration as success factors for convergent products, arguing that closed innovation leads to more proficient new product development in converging environments than open innovation. This effect has been observed in a Korean environment and awaits validation in different settings. It nonetheless provides another example of ambiguity in convergence research, where Woo and Choi (2018), in contrast, identify external collaborations and knowledge recombination capabilities, particularly employees with an interdisciplinary research background, as crucial. Rikkiev et al. (2012) zoom into external collaborations under different product convergence types. The differentiating factors between product substitution and product complementarity include product features, relative product advantages for the customer, and determining the company position in the industry value network.

Among the ten studies focusing on the consumer perspective, three studies investigate the intention to purchase convergent products. While Holle et al. (2015) broadly identify success factors, Hur et al. (2012) observe that functional, epistemic and emotional values play a crucial part, moderated by consumer innovativeness. Moving on to more mature convergent products, Han et al. (2018) zoom in on the effects of product labelling on consumers' perception of convergent products.

Three additional studies bring to light the need for balancing producer offering and consumer demands. Han et al. (2009) revealed that consumers prefer non-converged products when technological performance is high, but prefer convergent products when technological performance is low, prioritizing convenience. Lee and Cho (2015) also tackled the relationship between existing and convergent products, categorizing convergent products and markets while also deriving consumer demand for each of them. Based on a technology acceptance model for internet protocol television (IPTV), Shin (2009) showed that firms need to be prepared to accommodate multiple consumer needs in a convergent product, e.g. usefulness and enjoyment in the case of IPTV.

Based on these insights, four studies revolve around successful combinations of product functionalities for convergent products. Foundational work by Gill (2008) introduced the notion of utilitarian and hedonic functionality to the convergence realm. Further studies by Azhari and Afiff (2015) as well as Correa et al. (2018) built on these insights, while Lee et al. (2013) used the Kano model to determine appealing functionalities for convergent products.

Reflecting its product and consumer lens, this strand is predominantly anchored in the marketing literature, complemented by social psychology and new product development. While the theory of consumption values (Sheth et al. 1991), consumer utility theory and utilitarian/hedonic functionality are borrowed from the marketing domain, the theory of reasoned action from social psychology builds the basis of technology acceptance models (Davis et al. 1989). However, studies with a focus on technology convergence tend to rely on concepts from evolutionary economics such as technology trajectories and knowledge recombination, rooted in strategic management. Thereby, quantitative empirical studies with mostly consumer surveys are the prevalent research design, complemented by one qualitative interview study.

Convergence steps and fields

As convergent products are an expression of converging market offerings, the step of convergence analyzed in this strand is the market level. Thus, through shedding light on various aspects around convergent products, all studies address market convergence, while mostly including technology or industry convergence as well. It is striking that convergent products are predominantly studied in the narrow realm of ICT, with one article including various converging industries. While converging technologies can be observed in a number of different areas, actual convergent products are far less frequent. Nonetheless, there are further convergent product already launched and established such as nutraceuticals and functional foods with fish oil (Drugs.com 2020) or probiotic yoghurts (Dannon 2020).

Table 6 Strand 4 Extant studies focusing on convergent products.

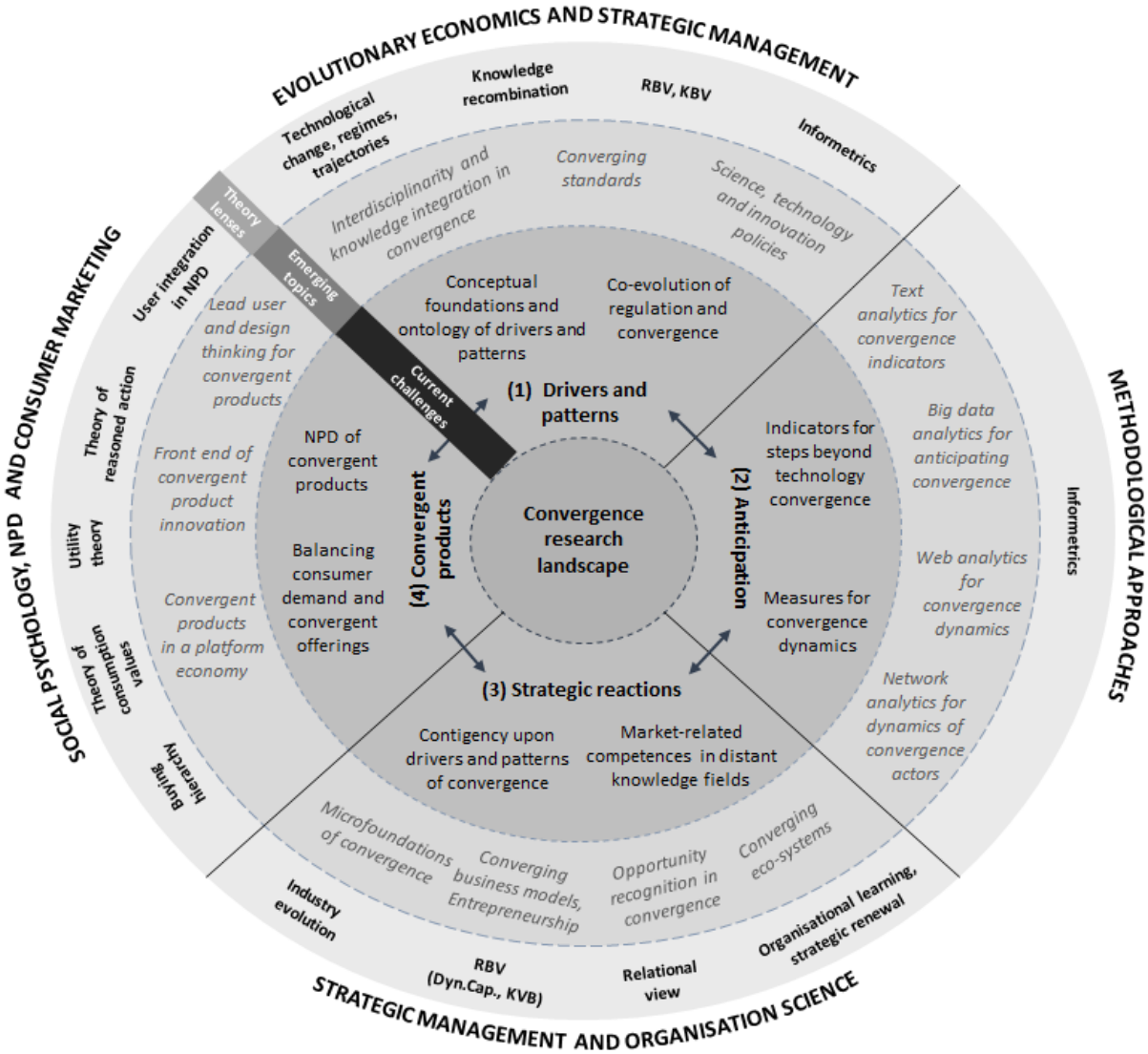
Articles	*Key issues explored*	*Theory lens/approach*	*Research design*	*Convergence setting*	*Step*	*AAC*
Han, Chung, Sohn (2018)	Impact of labeling of convergent products on consumer value perception	Marketing (consumer value perception)	Quantitative (survey)	ICT	MC	1.0
Correa dos Santos, Souza da Costa, Arruda Filho (2018)	Consumer value perception of convergent products with green attributes	Marketing (utilitarian vs. hedonic functionality)	Quantitative (survey)	ICT	MC	0.5
Woo, Choi (2018)	Firm specific factors behind developing convergent products	StratMgmt (KBV, KR)	Quantitative (survey)	Various	TC, MC	0.5
Azhari, Afiff (2015)	Coherence and congruence of converged products	Marketing (utilitarian vs. hedonic functionality)	Quantitative (experimental design)	ICT	MC	0.6
Holle, Hüsig, Dowling, Mohr (2015)	Success factors of convergent products by focusing on product concepts	NPD (product ecosystems)	Quantitative (survey)	ICT	MC	0.0
Lee, Cho (2015)	Framework for the market analysis of new convergent products	Marketing (consumer utility)	Quantitative (survey)	ICT	MC	0.8
Lee, Kim, Lee, Lee,	Links between corporate capabilities (organizational	NPD (ambidextrous NPD skills, corporate capabilities, external	Quantitative (survey)	ICT	MC	0.4

Yeon, Song, Kim (2013)	learning) and performance of convergent products	knowledge integration				
Lee, Lee, Garrett (2013)	Consumer valuation of convergent products, consumer attitude towards functionalities of convergent products	Marketing (Kano model, consumer research)	Quantitative (survey)	ICT	MC	2.6
Hur, Yoo, Chung (2012)	Impact of consumption values and consumer innovativeness on purchase intention for convergent products	Marketing (theory of consumption values)	Quantitative (survey)	Home Robots	MC	3.3
Rikkiev, Seppänen, Mäkinen (2012)	Collaboration success factors needed in a product convergent environment	Social psychology (theory of reasoned action)	Qualitative (interviews)	ICT	MC, IC	0.1
Han, Chung, Sohn (2009)	Effect of a convergent product on consumer preferences	EE (technology trajectories)	Quantitative (consumer data)	ICT	TC, MC	5.2
Shin (2009)	Technology acceptance model for IP-based technologies	Social psychology (theory of reasoned action)	Quantitative (survey)	ICT	TC, MC	6.8
Gill (2008)	Consumer valuation of convergent products	Marketing (utilitarian vs. hedonic functionality, theory of assimilation/ contrast effects	Quantitative (experimental design0	ICT	MC	8.6

Notes: EE=evolutionary economics, SC=science convergence, TC=technology convergence, MC=market convergence, IC=industry convergence, AAC=average annual citation, NPD=new product development

5. Synthesis of findings and avenues for further research

The literature review presented in this paper demonstrates that the evidence base of convergence is broad and heterogeneous, as relevant research has been carried out using a number of different perspectives, framed as strands of convergence literature. By grouping the articles according to the strands and the identification of theory frameworks used (based on Tables 3 to 6), a coherent framework of the extant literature body emerges (Figure 2). The framework is to be read clock-wise and from the inside out, starting with the four strands of convergence research. The strands are anchored in different theoretical foundations and span the perspectives on convergence research. Drivers and patterns (strand no.1), unlocking the phenomenon of convergence, draw on theory lenses rooted in evolutionary economics and strategic management. Anticipation (strand no.2), entrenched in informetrics, represents a methodological perspective on convergence. Strategic reactions (strand no.3) are based on strategic management and organizational science, reflecting a firm-centric perspective. Convergent products (strand no.4), drawing on consumer marketing and new product development, adds a market-centered perspective. Based on the analysis of the strands in Section 4, the two most pressing challenges in each strand are presented in the first layer. Subsequently, emerging topics in every theoretical perspective with the potential to tackle these challenges are depicted in the second layer.



559

560 **Figure 3** Framework of convergence research, integrating theoretical perspectives on convergence
561 research and main challenges, matched with emerging topics.

562 Source: Own figure.

563 **Synthesis of Strand No.1 Drivers and patterns, emerging topics and future research needs**

564 The analysis of strand no.1 clearly revealed that current research in this area is often facing inwards at
565 the phenomenon of convergence itself or rather loosely positioned in a variety of theories. The
566 foremost challenge of convergence research is, thus, to strengthen its theoretical foundations. The
567 perspectives of evolutionary economics and strategic management provide starting points to firmly
568 anchor convergence research in current theory. The respective theoretical lenses from other strands,
569 depicted in the outer layer of Figure 3, can be combined to develop a coherent theoretical foundation
570 of convergence research.

571 Studies on drivers and patterns of convergence focus largely on technological aspects, mostly using
572 patent analysis. Most recent studies in this domain confirm this finding, exclusively analyzing
573 technology convergence by means of patent analysis (Xu and Cheng 2021, Barbieri et al. 2020, Kim and
574 Lee 2020, Lee and Lim 2020, Son and Cho 2020, Tang et al. 2020). While regulatory aspects are covered
575 as well, but to a less structured extent, market-related analyses are a rare exception. There is no doubt
576 that patent-based analyses are a valuable means to shed light on the nature, antecedents and

mechanics of technology convergence. Nonetheless, as suitable, easily accessible and well-structured patent data might be, convergence research could be broadened by including further types of quantitative analyses as well as qualitative studies to develop ontologies for the drivers and patterns of convergence. This would then enable scholars to conduct cross-case comparisons to contribute to the more abstract level of patterns and drivers of convergence beyond the individual research setting.

Starting with drivers of convergence, a variety of developments leading up to a process of convergence might not be technology-induced and thus hardly accessible via patents. Examples are broader societal, political or environmental trends such as avoiding plastic waste, electric mobility or the increasing use of renewable energy. Moreover, as the findings depicted in Table 3 indicate, convergence at the level of technology is the topical perspective. However, science convergence as well as the overall relation of convergence to the general construct of knowledge integration at different levels of convergence seems to be less understood and presents a major challenge in current convergence research. Here, an analysis of the cognitive frames, and potentially their path dependence leading to knowledge corridors (Gruber et al. 2013, March 1991), as well as cognitive distance (Nooteboom et al. 2007) of different scientist and technology managers might foster our understanding of how knowledge integration and convergence relate to each other. Another interesting issue in this regard revolves around perceived disciplines and the involved cognitive distance (vom Stein et al. 2015). Even if there is a measurable distance between disciplines, are "hybrid" scientists, acquainted with multiple disciplines and spanning disciplinary boundaries, already observable and what are their meta-competences enabling them to integrate different fields of science?

As the drivers and patterns of the convergence process are likely to be dependent on the diversity of the converging fields of science, technology, market and industry, novel disciplines lend themselves to tackling the abovementioned challenges (Dingler and Enkel 2016, Klein and Falk-Krzesinski 2017, Whalen 2018). The ontologies of drivers and patterns could thus be based on a classification of interdisciplinarity, i.e. how different are the converging fields? Measures for the degree of interdisciplinarity could serve as a valuable starting point for such endeavors.

As the way in which scientific disciplines are organized undergoes a renewal process with the advent of convergence, novel areas such as synthetic biology drive novel inter-science domains. The same holds true for the technological step of convergence as one can observe in the classification systems of patents. Hence, the dynamics of how these emerging fields are regulated and how regulation co-evolves with convergence is another challenge for convergence research. Drawing on regulation and innovation (Marino et al 2019, Jaffe and Pamer 2006) and looking at science, technology and innovation (STI) policies (Paraskevopoulou 2012) seems promising in this context. The facilitation of emerging industries based on STI policies, for instance, shows potential to advance the regulation and standards perspective on convergence research (Faulkner 2009).

In this regard, the emergence of novel regulations and standards may trigger investment and, thus, foster convergence (Gauch and Blind 2015). However, the ongoing process of digitalization, with often ill-defined but only emerging industry standards, e.g. IoT, sensor and hardware communication, presents a very relevant field to study the interplay between regulation and convergence, rooted in the literature on standards and innovation (Allen and Sriram 2000). Despite the dynamics inherent in the ICT sector, other empirical examples of convergence deserve attention, e.g. the area of personalization, like personalized drugs, foods or cosmetics, which leads to an increased blurring of industry boundaries with major implications for regulatory frameworks.

Synthesis of Strand No.2 Anticipation, emerging topics and future research needs

The literature review reveals two main challenges with regards to anticipation. Firstly, it can be observed that the development of indicators is very much focused on technology convergence. Recent work in this area published after the closing date of the structured literature review reinforces this notion. Only one study investigates industry convergence (Waßenhoven et al. 2021), while six others target technology convergence (Cho et al. 2021, Choi et al. 2021, Lee and Sohn 2021, Sasaki and Sakata 2021, Feng et al. 2020, Kim and Sohn 2020). Despite the notion that science, market and industry convergence have to be identified on the basis of fuzzier and less structured data than technologies drawing upon patents, their importance should not be underestimated in order to holistically capture and anticipate the process of convergence in a certain area.

Secondly, the connection between different steps of the convergence process and the respective indicators is yet to be investigated. Hence, the dynamics within a process of convergence are still far from being clear-cut: How long does it take for the individual steps of convergence to unfold, assuming they are following a sequential logic? What is the time lag between the individual steps? What are the influence factors on their varying length and time lags, e.g. in high or low technology environments? The abovementioned framework of drivers of convergence could provide an initial structure to tackling these questions.

Anticipation of convergence thus calls for larger empirical studies and meta-analyses, comparing (steps of) the convergence process across different convergence settings. Novel methods arising in informetrics such as big data, text, web, and network analytics appear to be particularly useful in this context (Chen et al. 2012). These novel methods allow convergence researchers to tap into and combine previously unavailable data sources and methods of analysis to deepen and broaden the empirical basis of convergence research. Big data analytics and machine learning approaches for prediction (Agrawal et al. 2017) are based on data mining and statistical analysis and allows to analyze the vast amounts of data that have become accessible to convergence researchers over the past decade, e.g. event data from supply chains to identify value chain shifts in a setting of convergence. Kim and Sohn (2020) have already taken this up in their work on a machine-learning-based deep semantic analysis approach for forecasting new technology convergence. Text analytics could be used for a meta-analysis of previous work to identify and classify indicators for the steps of the convergence process. Web analytics, and specifically social media analytics, might be useful for developing additional indicators and shedding light on the dynamics at the interface between the steps of convergence. In particular, market convergence and the interface between technology and market convergence offer themselves as a playing field for social media analytics due to the use of unstructured data for identification. Network analytics, grounded in citation-based informetrics, can feed into convergence research to, for instance, detect and predict links between the actors in convergence networks, e.g. scientists, consumers or organizations (Jeong 2014). Feng et al. (2020) have taken further steps in this direction, combining network analysis and link prediction to anticipate technology convergence.

In sum, this strand could benefit tremendously in reaching out to new methods and approaches currently being developed, especially tapping into the connection between informetrics and the foresight domain of the TIM literature body (Mulroth and Gottke 2018, Rohrbeck et al. 2015). This not only triggers novel research questions with respect to foresight, but also helps to connect extant research in the foresight domain to the evolving convergence literature and related areas.

Synthesis of Strand No.3 Strategic reactions, emerging topics and future research needs

Strategic reactions are key to the entire literature body of convergence. Although sharing the theoretical foundation in strategic management, it is striking that this stream of studies appears somewhat independent from strands no.1 and no.2. The very few studies recently conducted in this area have not yet tackled this issue (Hsu in press, Li et al. in press, Thomas 2020). While no new theoretical lenses have been introduced, the connection between convergence and disruptive innovation, open innovation and service innovation have been strengthened. Hence, it would be desirable if studies on strategic reactions increasingly discussed these by taking into consideration the drivers and patterns of convergence. One can, for example, assume that strategic reactions are contingent upon types of convergence, for instance relating to Greenstein and Khanna (1997) that the case of substitutive convergence presents a stronger need for action than the complementary case. In this context, the strategic renewal body of literature (e.g. Tuncdogan et al. 2019) remains largely unexplored. In particular, the recent rise of the microfoundations perspective (Fellin and Foss 2005) seems very promising in adding to the current understanding of convergence. To this end, a dedicated analysis exploring managerial mental models (Hodgkinson and Johnson 1994) and cognitive frames (Hahn et al. 2014) may help to explain the antecedents of strategic reactions of firms involved in convergence settings.

Moreover, the present discussion is dominated by how to embark on new technological competences, while the question of how firms can build new market-related competences in a setting of convergence does not seem to be well understood. Conceptualizing convergence from a business model perspective (Zott and Amit 2010) could be a valuable starting point to tackle this challenge, presenting value propositions rooted in two different industries (Kodama 2014). In a similar vein, the question of how to collaborate in distant knowledge fields of convergence (Gruber et al. 2013) and how to build a larger ecosystem seems to be a major challenge. In this regard, the emerging ecosystems literature from a technology perspective (Markard and Truffer 2008) or a knowledge creation perspective (Van Krogh and Geilinger 2014) might be beneficial. A cross-fertilization of the convergence and entrepreneurship literature also seems promising. Especially, the question of opportunity recognition (Ardichvili et al. 2003) in distant knowledge fields and the role of startups (Gruber et al. 2013) seem promising. In addition, the impact of path dependent learning on opportunity recognition in emerging inter-industry segments (Bröring and Craemer 2019, Sheperd and DeTienne, 2005) as well as the orchestration of corporate-startup collaborations (Kohler 2016) and the resulting change in organizational identity (Tripsas 2009) seem important avenues for future research to understand strategic renewal in times of convergence.

Synthesis of Strand No.4 Convergent products, emerging topics and future research needs

The analysis of strand no.4 revealed that the firm perspective has just started to emerge, investigating success factors for developing convergent products. Hence, embedding convergence research in the domain of new product development, and thus stronger in TIM, presents a pressing challenge. How, for instance, does a lead user workshop (von Hippel 1988) or a design thinking workshop (Brown 2008) foster user driven designs if the product emerges at the borderline of two hitherto unrelated markets? Novel perspectives such as microfoundations of idea generation (Haas and Ham 2015) may also present opportunities to better understand the research and development of convergent products such as idea generation of these borderline products: How do ideas for convergent products emerge? What is the impact of interdisciplinary teams? Here, the specific TIM-related research body of the front end of innovation (e.g. Bröring et al. 2016) may inspire those questions.

The literature on convergent products from a consumer perspective is mainly rooted in consumer marketing, new product development and social psychology. At the same time, the convenience and the demand for one-stop-shopping presents an important driver for the emergence of convergent products, i.e. demand driven convergence. However, none of the studies make reference to the different drivers of convergence. Hence, an integrative view on drivers for convergence processes and outcomes, such as convergent products, seems important. Here, studies forecasting, assessing and integrating the technology-driven as well as the market-driven part of convergence similar to the roadmapping idea (Phaal 2004), thus integrating the supply and demand side of convergence (Pennings and Puranam 2001) seem promising to understand the overall drivers of convergence and how convergence at the technology end relates to the demand side. In relation to the latter, more studies are needed to further detail how to balance consumer demand and producer offerings with regards to convergent and dedicated products. For instance, the argument of Han et al. 2009, stating that at higher levels of technology, consumers prefer dedicated products instead of convergent ones, needs further validation. Does this argument also hold true on the B2B level? How would the result look like beyond ICT?

These questions demonstrate that the entire field of convergent products is just about to emerge. So far it approaches convergence predominantly through the lens of consumer marketing. However, it offers vast opportunities to be linked to both concepts and theories around new product development and user-driven design rooted in the TIM literature. Moreover, due to the paucity of prior research it seems evident that there is a strong need for further empirical studies validating the emerging theoretical concepts relating to convergent products.

6. Implications and avenues for future research

The presented framework of convergence research combines different perspectives on convergence, providing a concise and structured overview of the current research landscape of this evolving discipline of TIM. A key finding of this review is that most contributions have been inward oriented, e.g. understanding the dynamics of convergence itself. This is reinforced by the growing number of recent studies investigating drivers and patterns as well as the anticipation of convergence. In contrast, strategic reactions, despite being the largest strand of convergence research, and convergent products have gained comparably little attention in the last few years.

As a consequence of this inner focus, the scientific discourse on convergence has, to some degree, unfolded independently from theoretical underpinnings. The suggested framework (see Figure 3), particularly the challenges identified in each perspective and the emerging topics to address these challenges, provide opportunities to further connect convergence research to theoretical foundations from the TIM domain and neighboring disciplines. This structured and detailed overview provides researchers with new stimuli for future research to further develop the body of literature on convergence. Potential research questions, based on the current challenges and emerging topics identified in the framework, are summarized in Table 7. We hope that these questions can serve as a starting point for convergence researchers to use their unique knowledge base on drivers, patterns and anticipation of convergence to further integrate market- and firm-related aspects of convergence research. At the same time, these questions can be seen as an invitation to researchers from neighboring fields to enlarge the theoretical foundations of convergence research.

752 **Table 7** Avenues for future research.

Strand of convergence research	*Potential research questions*
Drivers and patterns	How could an ontology of drivers and patterns of convergence based on a meta-analysis of convergence cases look like?
	What are societal, political and environmental drivers of convergence?
	How do knowledge integration and convergence relate to each other in the light of cognitive distance?
	Are "hybrid" scientists, acquainted with multiple disciplines and spanning disciplinary boundaries, already observable? What meta-competences regarding knowledge integration do they share?
	How different are converging fields, based on a classification of interdisciplinarity?
	How are emerging fields of convergence regulated and how does regulation co-evolve with convergence?
Anticipation	What are antecedents eventually leading to science convergence, how can these be used in forecasting technology convergence?
	How long does it take for the individual steps of convergence to unfold?
	What are the influence factors on their varying length and time lags?
	How can text analytics be used for a meta-analysis of convergence research to identify and classify indicators for the steps of the convergence process?
	How can web analytics, and specifically social media analytics, be used to develop additional indicators for (the dynamics at the interface between) the steps of convergence?
	How can network analytics be used to detect and predict links between the actors in convergence networks, e.g. scientists, consumers or organizations?
Strategic reactions	How can strategic renewal contribute to explore strategic reactions to substitutive convergence?
	How can managerial mental models help to explain the antecedents of strategic reactions of firms involved in convergence settings?
	How can the business model perspective contribute to building new market-related competences, based on value propositions rooted in two different industries?
	How can different organizations collaborate in distant knowledge fields of convergence?
	How can actors build a convergent ecosystem? What drives leadership in these emerging eco-systems?
	How can managers recognize emerging business opportunities in distant knowledge fields?
	How can new data driven methods be integrated in forecasting activities helping companies to anticipate and timely react to trends of industry convergence?
	How to orchestrate corporate-start up collaborations in converging environments?
	What is the impact of convergence on organizational identities?
Convergent products	How does a lead user or design thinking workshop foster user driven designs if the product emerges at the borderline of two hitherto unrelated markets?
	How do ideas for convergent products emerge and what is the impact of interdisciplinary teams?
	How can drivers of convergence be related to convergent products?
	How to balance consumer demand and producer offerings with regards to convergent products?
	What is the role of servitization (evolution from physical products to product-service systems) in convergent products?

753

754 In addition to the indisputable theoretical relevance for convergence research, implications can be
755 derived for industry and policy. With the rising empirical relevance of the convergence phenomenon,
756 the overview of convergence research developed in this study first and foremost helps to build
757 awareness for convergence processes, including drivers, strategic options and convergent products.
758 The framework provides practitioners with a structure to categorize and evaluate current challenges
759 in converging environments. Corporate R&D units can build on and adapt the approaches and

methods presented to identify fields of convergence. The strategic reactions and the underlying case studies form starting points for management in shaping innovation strategies to close technology and market competence gaps in converging environments. In addition, the insights of this study are highly relevant for policy makers. Particularly the small number of studies focusing on standards regulation can serve as a signal for policy makers to increasingly engage in further areas of convergence, especially regulation-intensive ones such as nutraceuticals or energy storage.

We are well aware that we have chosen a conceptual approach to review the convergence research landscape, with the aim to contribute to increasing conceptual clarity. Also due to the still emerging and scattered nature of convergence research, a qualitative approach seemed most promising for a convergence review. However, since the research field is growing, convergence research would benefit from a complementary quantitative approach. In this context, co-citations networks can, for instance, uncover links between convergence researchers using different theoretical lenses and identify possible clusters of convergence research. Co-occurrence of keywords or semantic analyses are further options to shed light on the inner structure of convergence research.

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