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The influence of additive manufacturing on early internationalization: considerations into potential avenues of IE research

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Abstract

Novel technologies are key enablers for early internationalization. Researchers and experts imply that industry 4.0 (i4.0) technologies will be exploited by existing firms and new ventures to develop radical business models and market revolutionizing products and services, leading to the disruption of global markets. Additive manufacturing (AM) is currently emerging as one of many disruptive i4.0 technologies. This paper provides the first stepping stone for research into the influence of AM on internationalization in the context of new venturing. Reflecting on current technological trends in the global industrial ecosystem, this paper proposes four themes of particular relevance in guiding future research into the influence of AM on new venture internationalization. Firstly, we indicate that research is needed into the emergence of expert AM service providers and the consequent lurking disruption of the current global value chain. Secondly, we suggest research focused on the role of AM in facilitating increased customer interaction and how this impacts networking, which is a key to early internationalization. Thirdly, we highlight the need for research that acknowledges the current challenges to established legislation and institutions to provide insights into how AM technologies influence international new ventures in the age of i4.0. Fourthly, we propose that research is needed into how AM technologies are used by INVs to overcome and capitalize on regional difference in developing products and services. The paper proceeds to conclude on and summarize these themes. Lastly, further less developed avenues of research are explored.

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Resume
Les nouvelles technologies sont des catalyseurs pour une internationalisation Chercheurs et experts professionnels s'attendent que les technologies « i4.0 » vont être exploitées par les nouvelles ainsi que les entreprises existantes pour développer des modèles commerciaux radicaux et vendre produits et services révolutionnaires – facteurs qui vont perturber les marchés globaux. La production additive apparaît actuellement comme une de ces technologies i4.0 perturbantes. Cet article représente un premier tremplin pour la recherche dans l'influence de la production additive sur l'internationalisation dans le contexte de l'entrepreneuriat. Basé sur une réflexion sur les tendances technologiques actuelles dans l'écosystème industriel global, cet article propose quatre thèmes particulièrement pertinents pour la guidance des recherches futurs dans l'influence de la production additive sur l'internationalisation des nouvelles entreprises. D'abord, nous montrons un besoin de plus de recherche dans l'émergence des prestataires des services dans la production additive et la perturbation potentielle résultante de la chaine globale de valorisation. Deuxièmement, nous proposons des recherches avec focus sur le rôle de la production additive dans le soulagement d'une interaction croissante avec les clients et comme ce processus a un impact sur la construction des réseaux, élément clé d'une internationalisation précoce. Ensuite, nous soulignons un besoin des recherches reconnaissantes des défis actuels à la législation et les institutions actuelles pour une compréhension plus complète de l'influence des technologies de la production additive sur l'entrepreneuriat international dans l'âge d'i4.0. Nous proposons aussi qu'il y a un besoin de rechercher comment technologies de production additive sont utilisées par l'entrepreneuriat international pour surmonter et profiter des différences régionales dans le développement des produits et services. Finalement, nous présentons un résumé et des conclusions sur ce thèmes, ainsi que de trajets de recherche futurs.

Keywords Additive manufacturing · 3D printing · Industry 4.0 · Internationalization · INV

Mots-clés Production additive · Impression 3D · Industrie 4.0 · Internationalization · Entrepreneuriat international

Summary highlights

Contributions: This paper provides the first stepping stone to research into the potential influence of additive manufacturing (AM) technologies in an IE context.

Research questions/purpose: The paper reflects on current technological trends in the global industrial ecosystem and proposes four themes of particular relevance in guiding future IE research into the influence of additive AM technologies on new venture internationalization.

Basic methodology and information: Based upon a conceptually-based discussion of the emerging international business literature focused on AM and key insights on this topic from industrial experts, avenues for future research are developed.

Results/findings: Firstly, the paper indicates a need for IE research into the emergence of expert AM service providers and the associated potential disruption of the current global value chain. Secondly, it is suggested that research is needed into the role of AM in facilitating increased customer interaction and how this will impact networking and consequent internationalization of new ventures. Thirdly, the paper highlights a need for research into how the interplay between established legislation andAMtechnologieswill influence international new venturing in the age of i4.0. Fourthly, the paper indicates the need for research into how INVs can manage and apply AM technologies to overcome and capitalize on regional difference in developing products and services.

Theoretical implications and recommendations: Four current AM trends in the present industrial ecosystem are connected to IE research to explore the influence ofAMas a component in new venture internationalization activities.

Practical implications and recommendations: Existing firms, and in particular new ventures, will likely exploit i4.0 technologies in the near future to create a new breed of entrepreneurial opportunities, develop new radical business models, execute disruptive strategizing, and market revolutionizing products and services.

Future research suggestions: The emergentAMparadigm lessens the effects of deficiencies in national infrastructure, which is a typical characteristic of less developed economies. Accordingly,AMtechnologies likelywill provide away of reaching populations in countries or areas with underdeveloped overall business infrastructures. The need for research into this topical area is only trumped by actually acting to deployAMtechnologies to address these important issues.

Introduction

Novel technologies have frequently been demonstrated as key enablers in driving early internationalization and internationalization processes in general (Coviello and Cox 2006; Etemad et al. 2010; Hannibal et al. 2016; Nieto and Fernández 2005; Rialp et al. 2005a; Shane and Venkataraman 2003; Zahra et al. 2003). Consequently, much international entrepreneurship (IE) research has involved studies of the interplay between early internationalization and novel technologies such as the Internet and communication technologies (ICT) (Sinkovics et al. 2004) and life science (Rasmussen et al. 2011). Industry 4.0 technologies are presently emerging as key enabling technologies of the twenty-first century and will potentially change the global industrial ecosystem (D'Aveni 2018; Gambell et al. 2017; Ross 2016; Schwab 2017). Many researchers and expert commentators have claimed that i4.0 technologies are bound to be exploited in a global context by both existing firms and new ventures to create a new breed of entrepreneurial opportunities, develop new radical business models, administer disruptive strategizing, and market revolutionizing products and services (Lipson and Kurman 2013; Rayna and Striukova 2014). This paper draws the attention to the potential of a specific i4.0 technology – additive manufacturing (AM) – and provides a basis for research into the influence of AM technologies on

internationalization in the context of new venturing. Building on extant international business literature and key consultancy reports, potential research themes in relation to this research agenda are identified and elaborated on in this particular context.

The Fourth Industrial Revolution is epitomized by several emerging technological breakthroughs (Strange and Zucchella 2017) and represents new ways in which technology becomes embedded within products, services, industries, and societies in general (Hannibal and Knight 2018). Industry 4.0 refers to a number of constituent technologies. These include artificial intelligence, blockchain, additive manufacturing, nanotechnology, agile robotics, quantum computing, biotechnology, and the Internet of Things (Gambell et al. 2017; Schwab 2017). Some commentators have speculated that even more revolutionizing technologies such as mobile supercomputing, intelligent robots, self-driving cars, neuro-technological brain enhancements, and genetic editing will soon be incorporated in marketable products and services (Ross 2016; Schwab 2017).

The evidence of dramatic change caused by some of the constituent technologies of i4.0 has already been illustrated through numerous business cases (Bromberger and Kelly 2017; Müller et al. 2016). Based on this, many authors suggest that entire industries are set to be disrupted by the emerging i4.0 technologies (Gerbert et al. 2015). The breadth and depth of these changes will likely lead to the transformation of entire systems of production, management, and governance (Schwab 2017). I4.0 already tests the boundaries of our current understanding of the transforming market forces (Ross 2016) and challenges our attempts to understand how competences are to be adapted to attain profitable market positions (D'Aveni 2013; Strange and Zucchella 2017). This suggests that i4.0 technologies will offer numerous opportunities for international entrepreneurs and entrepreneurial firms in the near future. Yet these may be highly dependent on the specific industrial setting (Hannibal and Knight 2018).

Indeed, as one of the constituent i4.0 technologies, AM is currently emerging as a key enabling and disruptive technology (Lipson and Kurman 2013; Rayna and Striukova 2014). AM technologies allow for "3D printing" of physical objects (Nyman and Sarlin 2014). Historically, AM has been used for prototyping (Müller et al. 2016). However, AM has recently become increasingly relevant in a wide range of industries because of the mere development of the technology and the increased number of materials that the technology can handle (Gambell et al. 2017; Pfähler and Morar 2019). AM introduces a revolutionizing new fixed price per unit paradigm. Consequently, many expert commentators have claimed that the emergence of AM on a wider scale will likely challenge the fundamental logics of mass production (Baumers et al. 2016) and introduce the age of mass customization (Anderson 2012; Berman 2012; Campbell et al. 2011; D'Aveni 2013). Building on this, some authors have suggested that global production will gradually become more localized (Anastasiadou and Vettese 2019; Ben-Ner and Siemsen 2017; Laplume et al. 2016). As a direct consequence, managers of existing firms will need to reevaluate established business models, revisit knowledge taken for granted, and revise current approaches to international manufacturing and marketing (D'Aveni 2013; Gerbert et al. 2015).

However, research into the business aspects of these novel technologies is still sparse. Accordingly, in a recent literature review, Caviggioli and Ughetto (2018) indicate that although research into AM is currently gaining a strong momentum, the dominant part of the literature is focused on exploring the evolution of this technology

and its technical features. Yet many commentators and researchers have suggested that AM technologies are to be considered a key enabler for entrepreneurship, as this technology has the potential to facilitate fast transformation of innovative ideas into physical products, by which users are turned into entrepreneurs (Anderson 2012; Rayna and Striukova 2014; Ulmeanu et al. 2019). Some have even gone to the extent of arguing for focused teaching about AM technologies to motivate AM technology entrepreneurship (Ulmeanu et al. 2019).

Indeed, the international entrepreneurship literature shows that many international new ventures leverage opportunities through exploiting their competencies about novel technologies to reach international markets with revolutionizing products and services (Coviello and Cox 2006; Saarenketo et al. 2004; Zahra et al. 2003). Currently, there is a large body of IE literature focused on entrepreneurship and international new venturing in relation to ICT (i.e., industry 3.0 technologies) (Nieto and Fernández 2005; Sinkovics et al. 2004). However, despite much enthusiasm and the forecasting of a global AM market value eclipsing $12 billion in 2020 with a predicted annual growth rate surpassing 25% moving forward, the IE research literature on the business aspects of AMs is still sparse (Caviggioli and Ughetto 2018). This provides strong motivation to explore the potential of AM in an IE context as this would potentially provide detailed insight on an entirely new breed of entrepreneurial opportunities, radical and disruptive business models, innovative strategizing, and revolutionizing products and services. In addressing this gap in the IE literature, this paper provides the first stepping stones to research into the potential influence of AM technologies on international new venturing.

The paper proceeds as follows: Building on the sparse international business literature involving AM technologies, the next section relates to the current technological AM trends in the global industrial ecosystem to the likely impact of AM on IE. Four themes are identified and discussed in relation to potential avenues of research. At the end of the paper, we conclude and summarize each research theme in an overview (Table 1) listing the likely AM influence on the global industrial ecosystem and the contextualized impact on IE. Finally, less developed areas of interest are identified for further deliberation.

An outline of potential AM themes related to SME and INV research

This section outlines potential research themes, which in particular calls for thorough research into the likely consequences and impact of AM emergence on new venture activities and internationalization processes. The section topics are built around four current technological AM trends in the global industrial ecosystem. The trends discussed below are not to be considered a complete list of relevant research topics in relation to the influence of AM on international new venture activities nor have they emerged as a systematic literature review. Instead, each topic rests upon the emerging international business literature focused on the influence of AM technologies (Hannibal and Knight 2018; Laplume et al. 2016; Strange and Zucchella 2017) and key consultancy reports on this topic from industrial experts (e.g., Caffrey et al. 2016; Gambell et al. 2017; Ross 2016). The thematized discussions in the subsequent sections aim to guide considerations into forming the stepping stones to future research into the impact of AM technologies on new venture internationalization processes.

Table 1 Summary overview: impact of AM in the context of IE

Section headline	(Likely) Technological trend in the global industrial ecosystem	Likely influence of AM in the context of IE	Future avenue of research in IE
Disruption of the industrial ecosystem and emergence of AM service providers	The disruption of the industrial ecosystem and the associated value chain will lead to the emergence of the AM services provider	Radical change to the industrial ecosystem will act breeding ground to AM technology-competent international entrepreneurs who will execute radical new business models	Explore how different existing AM technologies provide the basis for early internationalizing technology start-ups
Increased customer interaction and new partnership dynamics	AM enable increased customer interaction and new partnership to form customize products and services	Am will impact key networking activities of INVs through influencing the relative power distribution along the supply chain	Explore how AM affects networking and the subsequent internationalization process of INVs on key dimensions
Challenges to IPR and the emergence of AM platform business	Challenges to current IPR caused by the emergence of AM platform services	The emergence of AM platform services will pose a challenge to current IPR regimes in the affected industries	Explore how AM technology platform providers make their services globally available while navigating a jurisdictional landscape
Regional diversification of AM services	AM support employing strategies involving regional diversification of products and services	AM technologies could assist INVs in adopting a regional approach	Explore how INVs use AM technologies to overcome and capitalize on regional difference in the development of products and services

Disruption of the industrial ecosystem and emergence of AM service providers

Expert commentators have laid specific emphasis on the ability of AM technologies to enable more flexible manufacturing setups (Berman 2012; D'Aveni 2013; Lipson and Kurman 2013). Many experts have suggested that AM will drive a revolution of global manufacturing which leads to the disruption of the current global industrial ecosystem (D'Aveni 2013; Lipson and Kurman 2013; Müller et al. 2016) through challenging the very foundation – economies of scale (Baumers et al. 2016). These radical changes would foster the breeding grounds for new radical business models in the global value chain which INVs presently operate in and by (Laplume et al. 2016; Rayna and Striukova 2014). On this basis, many authors have argued that in the near future, AM likely will enable local and even household manufacturing of many everyday items (Campbell et al. 2011; D'Aveni 2013; Winnan 2012). In principle, this would allow for new venturing based on local manufacturing or print service facilitation. Indeed, we already see examples of AM-enabled local production of, for instance, souvenirs, leading researchers to suggest the emergence of a new type of highly individualized souvenirs (Anastasiadou and Vettese 2019). In addition, a number of

revolutionizing manufacturing setups and end-user products have already illustrated the potential of AM in relation to this (Müller et al. 2016; Wohlers 2015). Many of these cases have been the result of technology-intensive international new venturing.

Despite these illustrative cases, empirical research indicates that actual broad-scale manufacturing in many industries seems not to be a reality of tomorrow (Blichfeldt et al. 2019) as a number of key challenges in terms of finish, physical characteristics, material composition, etc. are still very evident in relation to additive manufacturing of final products (Bak 2003; Hannibal and Knight 2018; Schneck et al. 2019). However, empirical research does suggest that AM will provide a basis for easier local production of more complex support tooling such as grippers, fixtures, molds, etc. (Blichfeldt et al. 2019). In principle, this will potentially provide existing firms as well as start-ups with a wide range of opportunities for manufacturing limited series, highly customized products, etc., as, for instance, setting up for customized engraving will be faster and less costly (Baumers et al. 2016). Coupling with other i4.0 technologies such as agile robotics adds exponentially to the array of these opportunities (D'Aveni 2013).

In addition to local production of support tools, empirical evidence shows that AM will enable local manufacturing of spares for servicing existing production lines (Blichfeldt et al. 2019; Zijm et al. 2019) for many manufacturing firms to maintain continued production without costly shutdowns. This provides a strong incentive to include AM competences in many manufacturing firms to support final goods production (Goldhar and Jelinek 1990). However, as an alternative to this, some authors have suggested an eminent emergence of AM technology-competent or expert service providers (Laplume et al. 2016) to externally supplement AM competencies in existing firms. Indeed, in high-technology industries, INVs often act as specialized sub-suppliers to other (larger) firms (Rasmussen et al. 2011). In principle, an Internet infrastructure is the only tool needed to connect in-house designers directly with an external expert AM services provider (Wu et al. 2013) who then subsequently turns bits into atoms (Nyman and Sarlin 2014). Given that technological competences are key drivers to success in technology-intensive industries, AM technology-competent international entrepreneurs will have the ability to recognize and pursue opportunities ahead even on established firms (Coviello and Cox 2006; Zahra et al. 2003).

The developments in the ICT sector during the past decades (Hyötyläinen 2007) seem indicative of the emergence of AM technology-driven service firms based on the development of existing or invention of new, AM technologies. One avenue of research would comprise exploring how different existing AM sub-technologies and emergence of new AM technologies will provide the basis for early internationalization of technology-based new ventures (and SMEs). Extant empirical research only brings sparse insights on international new technology start-ups based in i4.0 technologies such as additive manufacturing. However, research indicates that some of these technologies will provide a basis for new revolutionizing business models (Bogers et al. 2016; Rayna and Striukova 2014).

In relation to this area of research, only sparse empirical insights have been gathered on the role of AM technology-competent service providers that likely will be able to supply highly customized services. In the ICT sector, we have witnessed a strong tendency to outsource specific IT functions such as ERP and CRM systems (Hyötyläinen 2007), while other functions have been kept internally as part of a strategic decision. One might propose that this type of decision-making would also

be relevant in relation to some AM functions depending on the service and the specific type of AM technology needed. Accordingly, one area of research arising from the emergence of AM technologies would be to uncover how different types of AM technologies influence the current value chain characteristics, which INVs and SMEs presently operate in and by (Laplume et al. 2016). This would involve IE research retrieving insight on how these changes impact the early internationalization process of new ventures driven by AM technology-competent entrepreneurs.

Increased customer interaction and new partnership dynamics

The above discussion highlights how AM technologies provide a basis for increased customer interaction (Berman 2012; Bogers et al. 2016; Marzi et al. 2018). Consequently, this technology will have impact on relationship building between firms and their customers. Many INVs act as sub-suppliers to other firms, especially in industries characterized by new technologies (Rasmussen et al. 2011). This supports the notion that networking activities, such as partnerships and alliances, are key areas of interest in the study of INVs and SMEs (Achrol and Kotler 1999; Coviello and Munro 1995; Johannisson 1988). Thus, inspired by research conducted into other new technology industries, such as the pharmaceutical (Evers et al. 2012) and the ICT sectors (Nieto and Fernández 2005), another potential avenue of research in relation to the emergence of AM technologies would be to gain insights on how this particular technology affect the relationship building between the customers and the expert AM service providers.

With very few exceptions (Schneck et al. 2019), the actual broad-scale additive manufacturing of finished goods is not a reality of tomorrow in most industries. The present potential of AM resides in enabling faster tweaking and development of prototypes (R&D activities) and support tools to match the individual customer's demands (Bak 2003; Blichfeldt et al. 2019). Consequently, this will lead to faster inspection of the finished product (Marzi et al. 2018). This potential paves the way for more customized and tailor-made products (Da Silveira and Borenstein 2001) developed through collaborative projects with a specific manufacturing SME or INV (Öberg 2019).

In connection to this, insights from the pharmaceutical industries (Evers et al. 2012) and the ICT sector (Saarenketo et al. 2004) have indicated that different types of dynamic capabilities and learning are developed when comparing outcomes from short- and long-term collaborative projects between suppliers and customers. For example, there is a clear indication through long-term projects that INVs will hone regenerative dynamic capabilities and that this may come at the expense of incremental dynamic capabilities (Evers et al. 2012). Research has shown that the difference in these dynamics impacts the internationalization processes of the partnering firms. This has led researchers to suggest that the internationalization process of small and specialized high-technology firms unfolds through alternative patterns to those we see in more mature industries (Knight and Cavusgil 1996; Saarenketo et al. 2004).

Typically, the internationalization process of high-technology firms, and in particular INVs, involves collaboration with key (local) partners (Blomqvist et al. 2008; Coviello and McAuley 1999; Oviatt and McDougall 1994). However, including partners in ongoing projects requires disclosing key knowledge, which could be the key to their competitive advantage (Blomqvist et al. 2008). Consideration into these issues can be dated back to

Coase (1937) and the later developments by Williamson (1979). Indeed, by using this terminology from transaction economics, many high-technology SMEs and INVs are characterized by idiosyncratic knowledge creation and high asset specificity. In addition, their activities are often performed in highly uncertain international contexts that are prone to opportunistic behavior. To counteract opportunistic behavior, switching from one partner (e.g., supplier) to another is typical very costly as it is often difficult or even impossible to seek out a new supplier (Richardson 1993) due to idiosyncratic knowledge creation. This is especially true in high-technology industries where firms need to continuously reconfigure their existing resources (Zahra et al. 2003).

However, in viewing AM technologies, it may be observed that the key characteristic of this particular technology is that it facilitates flexible setup for small production series without the heavy costs induced by recalibrating the production setup (Baumers et al. 2016; Pfähler and Morar 2019), which is typically closely tied to traditional manufacturing techniques. This suggests that AM technologies will introduce lower switching costs, since there is not necessarily an initial cost associated with calibrating to new manufacturing specs. In turn, this suggests that customers will be inclined to switch suppliers more frequently depending on the exact competencies they pursue, the price of the service, and/or the location of the manufacturing partner (Berman 2012; D'Aveni 2013). Yet, on the other hand, through enabling more customized and tailor-made products (Da Silveira and Borenstein 2001), AM technologies may provide an incentive toward long-term partnerships. Indeed, recent research indicates that the introduction AM will potentially redistribute the power balance between different actors along the supply chain (Öberg 2019).

Given these considerations, studying how AM technologies will influence the internationalization process of new ventures is needed. It remains to be empirically researched how AM technologies will impact and perhaps disrupt customer interaction dynamics as we know them. Will AM technology add to the inclination toward opportunistic behavior, or will switching costs still play an important role in partnership based on AM technology competences? Existing research indicates that both tangible and intangible technological resources can impact the early internationalization process of new ventures on a number of dimensions (speed, degree, etc.) (Zahra et al. 2003). This area of research has been frequently studied in relation to high-technology INVs building partnerships, strategic alliances, opportunity development, etc. throughout the internationalization process (cf. Dib et al. 2010; Hannibal 2017; Peiris et al. 2012; Rialp et al. 2005b). However, it remains to be researched how AM technologies will impact these inherent features of new venture internationalization.

Challenges to IPR and the emergence of AM platform businesses

In close connection to the emergence of AM technologies, current developments indicate a growing conflict between digitalization of physical goods and current international trade policies (Bradshaw et al. 2010; Lipson and Kurman 2013). One key observation is how the current treatment of intellectual property right infringement is further increased by the spread of AM technologies (Bradshaw et al. 2010) through providing access to hacks of existing products (Strange and Zucchella 2017). This growing conflict needs to be addressed through IE research to achieve insight into the early internationalization of AM technology-based new ventures.

As is the case with all the i4.0 constituent technologies, the full potential of AM technology is found in the interplay with other technologies (Strange and Zucchella 2017), such as web 2.0 applications (Gao et al. 2015). Web 2.0 comprises of web-based technologies that feature dynamic content, often through engaging user-generated content. The potential of AM technologies has already become evident in many industries through the many examples of international start-ups. Technology start-ups such as Thingiverse, GrabCAD, and Printspace3D base their business on user-generated content to provide downloadable pirate versions and add-ons to existing products in online depositories. As an example, Lego hacks in the form of STL files (i.e., digital representations) of specific hats, wheelchairs, pistols, and other add-ons have been available online for a while (Grunewald 2016) alongside instruction manuals for printing the standard bricks (Dramaticlron 2017; Hroncok 2017).

On one hand, letting customers provide content to the product portfolio could of course prove a viable change in the business model for many existing firms. However, the very nature of their operations greatly challenges the present dynamics of management of intellectual property and the associated legislation (Bradshaw et al. 2010; Tran 2014). For years the development, management, and distribution of user content via platform-based services have been a key part of many of the business models of major players in the ICT sector (Houser and Voss 2018; Sinkovics and Penz 2005). Brouthers et al. (2016) introduce the term I-Business to describe the type of firms that "offer a platform that allows users to interact with each other and generate value through user co-creation of content" (Brouthers et al. 2016; p516). Thus, unlike other businesses, an I-Business such as Airbnb or Uber does not generate value through selling products or services. Instead this type of firm provides (and owns) a platform for exchange of information. In addition, it allows users to buy and sell to, or barter with each other (Brouthers et al. 2016). This family of businesses has surfaced as international start-ups in many different industries during past 5–10 years, and the platform logic seems particularly relevant in relation to AM technologies.

In principal, as 3D printing becomes an everyday technology, competitors and hackers can scan and replicate otherwise patented goods (Steenhuis and Pretorius 2017; Weller et al. 2015). Online depositories will – and already do to some extent – allow for easy spread and procurement of the proprietary digitalized designs of a vast array of parts and finished goods (Desai and Magliocca 2013). The music and (tele-) visual industries have already been disrupted by similar forces, which have overturned established business models and challenged the traditional management toolbox (Davis and Zboralska 2017). We have seen a number of platform-based international start-ups such as Spotify, Netflix, Strife, etc. arise on the back of streaming technologies that feed on large depositories of music and/or visual product such as film, series, and sports.

Observing these services, it seems likely that the model they are based on could be translated into a depository of blueprints or "wikis-of-things" (Ratto and Ree 2012). A "wikis-of-things" could enable the distribution, sharing, and co-creation of an array of printing designs for physical products (Anderson 2012; Winnan 2012). Indeed, currently AM technology-competent users already upload and share three-dimensional drawings of an array of objects and products on platform depositories (Lipson and Kurman 2013; Weller et al. 2015). Some of these platform-based international new ventures such as Thingiverse, GrabCAD, and Printspace3D allow members to download and print objects and if necessary tweak them to match individual needs (Pearce

et al. 2010; Winnan 2012). This transaction is often associated with either a membership fee, a one-time payment, or based on peer-sharing, since individualized design can again be uploaded to provide further content to and be shared on Thingiverse's platform, for instance.

Although the emergence of platform-based firms is a very recent trend, it has already proven to be a challenge to the existing institutional norms of intellectual property rights in the affected industries (Bradshaw et al. 2010). The original manufacturers currently own the digital designs for components, products, and parts of products. With the emergence of AM technology start-ups providing depositories of blueprints or "wikis-of-things," original manufactures likely will be increasingly challenged in protecting their proprietary assets as we progress into the next decade (Ratto and Ree 2012; Rayna and Striukova 2014; Steenhuis and Pretorius 2017; Weller et al. 2015). This will potentially create tension between the established institutional setting and the many potentially emerging AM technology-based platform services. Research has only provided very little insight into the internationalization process of (more traditional) digital platform providers (Ojala et al. 2018; Romanello and Chiarvesio 2019). Even less is known about how AM technology platform providers make their services available to a global market while navigating a jurisdictional landscape.

Regional diversification of AM services

Many observers have highlighted the comprehensive policy implication of i4.0 constituent technologies (Lu and Da Xu 2018; Weber 2010). As an example of these wide-ranging impacts, all European firms and every European citizen have already been impacted by the changing legislative landscape through the introduction of the European General Data Protection Regulation (EU-GDPR.org 2018; Pardes 2018). The GDPR provides a regional guideline for all firms operating within the EU, while operating in other regions involves other regulatory constraint as well as opportunities (Diker Vanberg and Ünver 2017). The digital platform services, like Google and Facebook, are arguably well-known examples of ICT-driven firms that have been exploiting differences in the jurisdictional landscape to base unique market opportunities and maximize their business efforts (Houser and Voss 2018).

Potentially, AM technology-based platform services are set to integrate diverse regional (juridical)-based product strategies, more closely linked to local market and customer needs (Bogers et al. 2016). This type of strategy has already been seen in the media industries, where ICT-based firms such as Netflix and HBO have offered different access to bit-based media product depositories from their inception based on the regional and thereby jurisdictional location of your streaming device.

For many INVs, especially those acting in niche or highly-specialized markets, meeting specific needs is already a critical component in the development of superior products and services (Knight 2000). Accordingly, understanding changing customer needs and local demand conditions is of vital importance for adapting products and services to local, regional, or country-specific requirements to achieve international growth (Cavusgil et al. 1993; Ramarapu et al. 1999). However, developing alternative product variations through local adaptation has traditionally involved significant cost (Cavusgil et al. 1993). The tourist industry has already seen experimentation with customized/individualized 3D-printed souvenirs. This has led some researchers to

suggest that AM will disrupt the significant revenue streams for heritage and tourism attractions (Anastasiadou and Vettese 2019). In turn, this will push managers to radically rethink this highly location-dependent commercial setup.

In the traditional industrial ecosystem, firms produce standardized goods to attain economies of scale and simplify production (Jain 1989; Theodosiou and Leonidou 2003). Yet the ability to develop unique products tailored to local markets has been argued to be one of the key characteristics of early internationalizing firms and in particular "born globals" (Knight 2000; Knight and Cavusgil 2004). Potentially, AM does facilitate innovation and development through customer interaction (Berman 2012; Bogers et al. 2016; Marzi et al. 2018), which has been suggested to enable INVs and more generally SMEs to respond to changing conditions in the local market or local differences (Knight 2000).

Potentially, AM technologies could assist INVs (and SMEs in general) in adopting a regional approach. This approach has already been adopted by the digital streaming services. Many of these such as HBO and Netflix facilitate a diversity of local or regional version products being marketed in parallel at the same time. One way of managing this could be through adoption of strategies involving one common depository that allows access depending on the region the customer (user) or the 3D printer is currently in. In addition, this business model could also involve differences in the type of access depending on the region. The difference could span mere downloading capability to an access which enables user co-creation of specific elements or the entire product.

Researchers agree that the current regulative guidelines are already being overrun by the developments in many industries (Bradshaw et al. 2010; Desai and Magliocca 2013) and may therefore be inadequate in providing a framework for international business in the very near future (Berman 2012; Petrick and Simpson 2013). Other digitalized services are still struggling to navigate the regional differences in terms of IPR. This suggests that there will be a strong need for research, which considers the interaction between established (regional) legal norms and technological development to gain insights into the potential impact of AM technologies on the activities and strategizing of INV managers in the age of i4.0. Indeed, the development of a product or a service could very well be administered in a jurisdictional region with relative loose restriction while capitalizing on the finished product in other regions. Consequently, this research would include studies of how INVs use AM technologies to overcome and capitalize on regional difference in the development of products and services.

This research could be particularly relevant in the context of emerging markets as many commentators argue that the diffusion of AM technologies in the near future will greatly assist in leveraging sustainable improvement in the living standard in these areas (Rauch et al. 2016) partly due to the effects from individuals gaining the ability to efficiently print many goods taken for granted in the advanced economies such as food containers, shoes, bicycle spare parts, etc. (Hannibal and Knight 2018).

Conclusion and summary

This paper reflects on the impact of AM technology on early internationalization in the context of new venturing in particular. Accordingly, it adds to the research focusing on

the role of new technologies in the (early) internationalization of firms (Etemad et al. 2010; Hannibal et al. 2016; Nieto and Fernández 2005; Rialp et al. 2005a; Shane and Venkataraman 2003). Researchers and expert commentators agree that existing firms (and in particular new ventures) will exploit i4.0 technologies in the near future to create a new breed of entrepreneurial opportunities, develop new radical business models, execute disruptive strategizing, and market revolutionizing products and services (Lipson and Kurman 2013; Rayna and Striukova 2014). In this context, this paper has identified and discussed four current AM technological trends in the present industrial ecosystem, which are especially relevant for research into the influence of AM technologies as component in internationalization activities in general and international new ventures in particular. Table 1 summarizes each research theme, listing the (likely) influence of AM on the global industrial ecosystem, the contextualized impact on IE, and indicates the associated avenues of IE research. Each of the themes presented in the summary table is elaborated in the following paragraphs. Subsequently, we conclude the paper by discussing less developed IE-related research themes that call for further studies.

Firstly, the disruption of the industrial ecosystem and the emergence of the AM service provider are advanced as a current trend, which need particular attention in connection with IE research. We argue that this is based on the exponential development of AM technologies and their likely broader-scaled use in the near future (Schwab 2017). This has led some authors to suggest that in addition to building in-house AM competences, many existing firms will turn to technology-competent AM service providers (Laplume et al. 2016) to externally supplement AM competencies. We propose that this environment, characterized by radical change to the current industrial ecosystem, will prove to be the breeding ground for technological competent international entrepreneurs to create new radical business models in the global value chain which INVs presently operate in and by (Laplume et al. 2016; Rayna and Striukova 2014). Accordingly, one avenue of research would comprise exploring how different existing sub-technologies and the emergence of new AM technologies will provide the basis for international technology start-ups and influence their internationalization trajectories.

Secondly, we suggest that AM technology will impact on relationship building between firms and their customers. AM technology will provide a basis for increased customer interaction and new partnership dynamics (Berman 2012; Bogers et al. 2016). This aligns with the notion that networking activities are an essential part of the internationalization process of these INVs (Coviello and Munro 1995; Johannisson 1988) especially in industries characterized by new technologies (Rasmussen et al. 2011). Recent research posits that AM technologies influence the relative power balance between different actors along the supply chain (Öberg 2019). This suggests that the emergence of AM will likely be followed by new partnership dynamics. Accordingly, research is needed into how this particular technology affects networking and the subsequent internationalization process of INVs on key dimensions such as speed, degree, mode, etc. (Zahra et al. 2003). This research could find inspiration in the existing literature which focuses on how different "families" of novel technologies such as pharmaceuticals (cf. Evers et al. 2012) and ICT (Nieto and Fernández 2005) affect the networking activities and subsequent internationalization trajectories of new ventures.

Thirdly, expert commentators have argued that AM technologies likely will represent a fundamental challenge to current institutions and legislation through increased risk of IPR infringements (Bradshaw et al. 2010). For decades, intellectual property rights have epitomized the legal institutions surrounding national as well as international markets. The so-called I-businesses (Brouthers et al. 2016) or platform service providers have surfaced as international start-ups in many different industries during past 5–10 years. The nature of this family of firms has proven to be a challenge to the present dynamics in managing intellectual property rights (Tran 2014). The relevance of this type of firm in relation to AM technologies is already seen in niche industries. However, the emergence of AM technologies on a broader scale will probably expand the array of physical objects exponentially, which can be shared, downloaded, and printed. Presently, there is only little IE research into the early internationalization process of digital platform providers (Ojala et al. 2018; Romanello and Chiarvesio 2019) and a lack thereof in relation to AM technology-based platforms. This warrants research into how AM technology platform providers navigate the shifting jurisdictional landscape (Berman 2012; Petrick and Simpson 2013) while making their services available for a global market.

Fourthly, we highlight regional diversification of AM services as a potential theme which IE researchers could study. INVs basing their business on AM technology-based platform services will have a strong basis to integrate diverse regional (juridical) product or service strategies which closely match local markets and customer needs. This type of strategy has already been observed and studied in other digitalized industries such as the media. One of the key characteristics of AM technologies is that they have the potential to support development and innovation through (local) customer interaction (Berman 2012; Bogers et al. 2016; Marzi et al. 2018). Research has demonstrated a strong link between the ability to develop unique products tailored to local markets and early internationalizing firms and in particular born globals (Knight 2000; Knight and Cavusgil 2004). On this basis, AM technologies are set to influence the activities and strategies of INV managers. Accordingly, retrieving insights on how AM technologies can be applied to overcome and capitalize on regional differences is needed.

Further avenues of research and closing remarks

It has already been stressed that the research themes highlighted in this paper are not to be considered a complete list of relevant topics in the discussion of how AM likely will influence the early internationalization of technology new ventures. This section presents a set of less mature thoughts on IE-related research that likely will become important themes in the coming years in relation to the emergence of AM. Each of these avenues calls for further elaboration by expert researchers in the relevant disciplines.

One avenue of enquiry could take point of departure in observing that new technology-based firms often locate in clusters to gain access to institutional resources and benefit from industry-specific local business support. A key characteristic of these clusters is high levels of interfirm networking (Keeble et al. 1999). In many cases, these firms have shown exponential growth rates, which have spurred the attention of policymakers and researchers (Mason and Brown 2013). Consequently, much research

has focused on ICT-based firms concentrated in places such as Cambridge in the UK, Lund in Sweden, and of course the world-renowned Silicon Valley (Cooper and Folta 2017). The same tendency is evident for other new and still-emerging technologies, such as robotics and pharmaceutical products. This provides a strong incentive to research how AM technology-based firms (geographically) organize in relation to other firms. It has yet to be systematically recorded whether the tendencies and processes observed in AM-based INVs and SMEs match firms based in "traditional" Internet and communication technologies. This type of research would provide key insights for policymakers to develop support structures to secure the prospective exponential growth potential for AM technology-based SMEs and INVs.

Secondly, attention also needs to be guided toward how AM technologies will fundamentally change the nature of manufacturing work. Knowledge workers will become an even more central piece in the strategic thinking of manufacturing firms as machines take over traditional manual labor (Müller et al. 2016). Recruitment, training, and managing this workforce will be crucial for manufacturing firms, as competition shifts from current focus on products and markets to that of mastering cutting-edge manufacturing process technologies, which allow for efficient and effective use of these technologies to achieve competitive advantage.

A third highly relevant area of research, which has only been touched upon in this paper, is the role of AM technologies role in doing business in emerging and developing markets. The emergent AM paradigm is bound to lessen the effects of deficiencies in national infrastructure, which is a typical characteristic of these less developed economies – at least in rural areas. AM technologies will probably provide a way of reaching the population in countries or areas with underdeveloped overall business infrastructures and scant transportation infrastructure (Hannibal and Knight 2018). Currently, commercial printers with the ability to print complex materials and metals are very expensive and complex to operate. However, their less expensive desktop counterparts have proven to be a viable tool in reaching and addressing the urgent needs of the population in developing countries (Pearce et al. 2010).

As a case example, Field Ready® has successfully employed AM technologies to provide disaster aids in rural areas in developing countries such as Haiti, Nepal, and most recently the Bahamas. Field Ready®'s business concept involves shipping of both printing materials and 3D printers to areas hit by natural disasters. Firstly, this enables immediately deployment of the 3D print technology to address emergency needs such as medical appliances, water filters, etc. Subsequently, and in the long-run perspective, the printing capacity can be shifted to facilitate sustainable development of the area through building up the printing skills of local users. Ultimately, this long-term goal involves building a basis for local entrepreneurship. Indeed, transporting printing materials to the location is still needed, but determining the use of this material can be done onsite to meet immediate needs (e.g., plastic clamps, food container, tooth brushes, sandals, bicycle spares, etc.). Even functional housing materials can be manufactured if the right material is supplied (Buswell et al. 2008).

In a larger perspective, some researchers have speculated on the use of waste materials such as plastic bags, bottles, etc. as print material feeding stock offers an appealing and highly potent alternative to transporting such materials from outside. Waste materials, in particular plastic waste, are found in abundance in many developing countries (Al-Khatib et al. 2010). Reusing waste material could rid local AM capacity

from the dependencies of external supplies of printing materials and decrease dependency on foreign assistance in the long run. In effect, this could instill a sense of local empowerment. Through this, AM can facilitate not just sustainable development in less advanced rural areas in developing countries but also assist in addressing one of the fundamental problems in many of these countries. They find themselves struggling with the exponentially amassing amount of waste, which seems to be the collateral damage from climbing the ladder to becoming a developed country.

This particular area of research warrants a thorough study of the potentials of AM technologies not just in relation to commercial markets but also in relation to addressing the wider ranging social issues. It could be argued that the need for research into this topical area is only trumped by actually acting to deploy AM technologies to address these important issues. Indeed, this could be the litmus test of the potential of AM technologies as a driver to new venture internationalization in an i4.0 era.

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