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Entrepreneurship as an Innovation Driver in an Industrial Ecosystem

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Abstract Understanding how a new digital technology can translate into a valuable innovation is a challenge for established players and new entrants. For industrial players in an ecosystem, it can be both a threat and an opportunity. Furthermore, the new technologies open collaboration opportunities between corporates and start-ups. But it remains unclear what are the consequences of opening up and whether it has an impact on the innovation dynamics in the industrial ecosystem.

We use the case of the wind industry in Denmark, as a maturing industrial ecosystem, to study when and how the new entrants (technology entrepreneurs) have had an impact on the innovation dynamics. We first combine archival data with interviews to build a historical account of the evolution of the industrial ecosystem; then we incorporate data from the new entrants in the industry to specify the types of innovations that the most recent digital technology entrepreneurs have triggered.

The results suggest differences in the innovation dynamics depending on the value chain position. While some activities have remained rather closed (for instance, the technological development of the core elements in the wind turbines), the operations and maintenance activities have profited from digital technologies introduced by new entrants. Using these insights, we present and discuss suggestions to institutional actors interested in protecting the innovation leadership of their regional industrial ecosystems.

Keywords Innovation ecosystem · Digital entrepreneurship · Wind industry · Digital innovation

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1 Introduction

New technologies have set a whole new standard of innovation with constant groundbreaking innovation. Recent examples are the development of digital technologies such as drones, AI, IoT, VR, or Blockchain (Cohen et al. 2017). Established industrial ecosystems often observe these emerging digital technologies as a threat but also as an opportunity. Examples of the use of drones to support maintenance operations (PwC 2016) or IoT sensors data to improve supply chain operations (Li 2013) provide support for the latter.

The non-digital industrial players often struggle to keep up with the digital innovation pace; see for example the case of Kodak (Lucas and Goh 2009), even losing the attention of institutional actors and investors. This phenomenon can not only occur in traditional industries such as automotive or general manufacturing, but also in recently emerged industrial ecosystems such as the renewable energy industry. Against this backdrop, we would expect that the interaction between new technology entrepreneurs (i.e., digital start-ups) and industrial ecosystems could have a positive effect on the innovation pace of the established ecosystems and in their overall competitiveness (Nambisan and Baron 2013). Still, we know little on whether and how this process of interaction and co-evolution unfolds, leaving open the intriguing question of to what extent do entrepreneurs contribute to the introduction of new technology innovations in industrial ecosystems? We examined this question focusing on digital innovation to see if the characteristics of digital technologies facilitate the participation of new entrants.

In order to describe how this process occurs, we engage in the study of an industrial ecosystem under competitive pressure. We selected the case of the leading players in the wind industry (Vestas and Siemens) as it is an industrial ecosystem (mostly located in Denmark) that is under intense pressure to increase its innovation pace. The recent reference on how the solar energy industry pioneers lost its leading manufacturing position to cost-oriented producers (Zhang and White 2016) has triggered an urgent search for innovation opportunities to fend off new competitors.

We combine archival data and interviews with experts and actors in the industrial ecosystem to find answers to our research question. We first present a historical account of the innovation dynamics and the evolution of the wind energy innovation ecosystem. Building upon the interviewees' insights, we detail the new entrants' interactions and contributions to the challenges and opportunities in the industry.

Our data suggests that the entrepreneurs' contribution is strongly influenced by the different dynamics in the value chain activities. While the core wind energy technology development has become a rather closed process, the operations and maintenance activities have opened opportunities for new entrants introducing digital technologies.

The findings from this study contribute to the emergent literature on the interaction between innovation ecosystems and technology-driven entrepreneurial ecosystems (Thomas et al. 2017). We also generate valuable practical insights to institutional actors interested in protecting the innovation leadership of their regional industrial ecosystems, suggesting the need for a more active role in order to keep the value-added activities in the region.

We start with a review of the recent discussion on innovation and entrepreneurial ecosystems. We continue with a presentation of our research design and data sources. Then, we present a historical account of the wind industry ecosystem evolution and our findings from the fieldwork interviews. Finally, we outline the implications and takeaways for researchers and industry participants.

2 Innovation and Entrepreneurial Ecosystems

It is difficult to find a more popular word in business and management discussions than ecosystems. The concepts of innovation ecosystems and entrepreneurial ecosystems are often used in business and policy discussions. It appeared as a new term to discuss about the necessary actors and relationships in order to have innovation and/or entrepreneurship in a region (Ritala and Almpanopoulou 2017).

From a research perspective, the increasing popularity of the term raised some questions from scholars. One of the strongest critiques is the recent piece by Oh et al. (2016) that questions why the prefix eco- is used; the authors argue that most innovation ecosystems are not natural emerging systems but instead driven by key actors that push forward the innovation. The basic definition of an innovation ecosystem as a diverse group of organizations that co-evolve and co-create value (Adner and Kapoor 2010) can be ambiguous, in particular if we compare it with other existing concepts such as clusters or regional innovation systems (RIS).

2.1 Ecosystems, RIS, and Clusters

What makes an innovation ecosystem different from a cluster or a RIS? Clusters have a strong regional focus; they are agglomerations of organizations that reinforce the productivity of each other and strongly benefit from their geographic proximity. Plus, there is the idea that regional clusters compete against other clusters in the same industry across the globe; this explains the interest of policy makers to promote and support them to keep their international competitiveness (Scaringella and Radziwon 2017). The regional innovation systems (RIS) are broad public initiatives to facilitate innovation activities in a region; a common example are triple-helix initiatives that aim to increase the collaboration between university and industry in a region (Ritala and Almpanopoulou 2017). The differential aspect of innovation ecosystems is that they are market driven, meaning that even if the government or public institutions play a role in it, it is mostly the private actors that drive the co-evolution of the value creation and capture activities.

This implies that innovation ecosystems are not limited to a region, having global connections and actors, and that the market demand is likely to be the driver of technological evolution and structure changes. These aspects are the differential elements that justify the use of the prefix eco- to differentiate them from clusters or regional innovation systems (Ritala and Almpanopoulou 2017).

2.2 Entrepreneurial Ecosystems

From a policy maker's perspective, global innovation ecosystems are market driven and led by large firms that influence on the pace and technological evolution, so there are limited options to influence on their growth and evolution. As a result, the discussion has moved toward the early stages of ecosystem formation, introducing yet another new type of ecosystem: entrepreneurial ecosystems. These share many similarities with the abovementioned innovation ecosystems, but also some differences that deserve specific attention.

Entrepreneurs are the key actors in this type of ecosystem, but instead of being industry specific, they grow around a specific underlying technology [e.g., nanotechnology (Colombelli et al. 2014)]. They are globally connected with other new entrants aiming to explore the potential applications of a still underdeveloped technology (Autio et al. 2018). In this context, the role of the government is to support networking activities or complementary resources (Spigel 2017), but the dynamism of the entrepreneurial ecosystem largely depends on the existence of specific technical knowledge actors coming from either the industry or universities (Stam 2015).

2.3 Interaction Between Entrepreneurial and Innovation Ecosystems

In their description of the different stages of an innovation ecosystem, Dedehayir et al. (2016) mention that in the later stages, as the ecosystem matures, it reaches a point where there is either self-renewal or death. In this stage, the leaders of the ecosystem play a vital role in the generation of new innovations and in the restructuration of the dependencies and roles in the ecosystem.

It is at this point where new entrants in the innovation ecosystem contribute to the exploration of new opportunities, introducing new technologies or new business models that could contribute to the overall development (Nambisan and Baron 2013). As entrepreneurs in technology-driven entrepreneurial ecosystems have to make a choice on application and location, they start interacting with existent innovation ecosystems. This generates arguably a tension between technology-driven entrepreneurs and market-driven firms, both competing at a global scale to attract resources and growth. Considering their different logics, our research question is to explore when and how do these new entrants contribute to the innovation ecosystem? This is a puzzling question as regional policy makers support nascent entrepreneurial ecosystems with the ambition to have a next generation of large firms that support the region' growth, but this might not always be the final outcome (Brown and Mason 2014; Spigel 2017).

3 Research Design

The wind industry has not yet reached full maturity, but it has become a global innovation ecosystem. It has been in constant transformation due to new technical and environmental conditions and boasts high innovation dynamics (Simmie 2012). It is a global innovation ecosystem that includes manufacturers, suppliers, research institutes, universities, utility companies, service providers, consumers, etc. The Danish wind energy industry is an interesting case to explore as it has been in the epicenter of the emergence and development of the ecosystem (Flyvbjerg 2004). Given the explorative nature of this research, we chose a case study research to study the contribution of digital technologies entrepreneurs as an innovation driver in an industrial innovation ecosystem (Eisenhardt 1989; Ravenswood 2011).

The data sources consist of archival documents and interviews. The case study is built with various data sources to represent the phenomenon coherently (Eisenhardt and Graebner 2007). The archival data consist of prior reports, news articles, and research on the innovation ecosystem of the Danish wind industry, reports from the Danish wind industry (including onshore and offshore actors and activities), newspaper articles, and articles about the historical development of the wind industry. In addition to the archival documents, interviews with actors in the ecosystem provided rich insights on the innovation dynamics and the contribution of new entrants. Interviews with experts, managers, and researchers in the ecosystem were carried out for a holistic dataset (Robinson 2014).

The interviews (semi-structured) were conducted between December 2017 and April 2018. Given our explorative approach for this research, we selected the first interview partners from our network, based on their active involvement in the ecosystem. Following the interviewee's recommendation and network, we selected further interviewees (snowballing approach).

We were careful in our sampling strategy to choose an equal number of observers (such as academic researchers) and active actors in the ecosystem. An overview of the interviewees and their background can be seen in Table 1. Finally, we used data from companies listed in Crunchbase (start-up funding database managed by Tech Crunch) to get an overview of start-ups in the ecosystem. Thereby we selected all start-ups which stated that they are corresponding to the wind energy industry, located in Denmark and which are founded after before 2006. We added some further start-ups to the list that we discovered during our research and which fit to the criteria.

Table 1 Interviews with wind energy industry ecosystem actors (December 2017–March 2018)

Role	Position	Background	Duration (min)
Engineer 1	Junior engineer at Siemens Gamesa	Master Student working at Siemens Gamesa	35
Engineer 2	Program manager at Danish Wind Industry Association	Leading Sub-supplier Development Program	240
Director 1	CEO and Cofounder	Founder and CEO of one of the main lifting and transportation providers in the wind industry	15
Director 2	CCO	CCO at an international turbine service provider and former Head of Product marketing at Vestas	25
Director 3	CEO and Cofounder	Service and repair start-up, which uses new digital technologies	35
Researcher 1	Professor for Wind Energy	Professor at SDU and former DTU professor	60
Researcher 2	Professor in Sociology, Environmental and Business Economics	Professor at SDU and consultant for Innovation and Business development	30
Researcher 3	Professor in Supply Chain Management	Professor at SDU	27

Source: authors' own table

For the data analysis, a triangulation approach was chosen by combining archival data, interviews, and desk research (Leech and Onwuegbuzie 2007). First, we built a historical account of the industrial innovation ecosystem after compiling facts and perspectives from our data sources. This historical account helped to identify key stakeholders and to assemble a value chain. During this process, we marked two processes, turbine development and park development, which split the innovation ecosystem. Prior research in the Danish wind innovation ecosystem, for instance, triple-helix taxonomy, provides an introduction into the innovation dynamics (Brink and Madsen 2016; Andersen and Drejer 2009). Next, we supplemented unacknowledged areas in both processes with interviews. Thereby, interview transcripts are integrated to enrich data with personal narratives and quotes.

To understand the phenomenon, we applied an iterative process of switching between data and theory. To provide further evidence of the entrepreneurial dynamics, we analyzed the list of start-ups in the Danish wind industry from Crunchbase. Using as search criteria their location in Denmark and that their description contains a connection to the wind energy. The total number of companies meeting these criteria was 21. Some of the listed companies, like Vestas, are, however, not part of the research object. For this reason, we exclude all companies which were founded before 2007. All companies which meet these for criteria are listed in Table 2 (in the results section).

Table 2 List of recent start-ups within the Danish wind energy ecosystem

Entry year	Start-up name	Product/service	Area in the value chain	Digital innovation
2009	Forida	Ultra-high-performance concrete	Turbine development	No
2007	Global Lightning Protection Service	Hardware lightning protection and digital lightning system that inspect turbine	Operation and maintenance	Yes
2008	Global Wind Service	Global technicians' supplier	Operation and maintenance	No
2016	KiteX	Drone wind energy	Turbine development	Yes
2014	Klenergy Tech	Store electric power with hardware solutions and blockchain technology	Operation and maintenance	Yes
2013	Power curves	Upgrading turbine blades panels	Operation and maintenance	No
2016	RopeRobotics	Unique blade repair by using robotics and additive manufacturing	Operation and maintenance	Yes
2013	Vaavud	Crowdsourced weather service	Operation and maintenance	Yes
2016	Wind Power LAB	Automated wind turbine blade defect detection and assessment through AI	Operation and maintenance	Yes
2008	Windar Photonics	Laser-based anemometer	Operation and maintenance	Yes

Source: authors' own table

4 Historical View on the Development of Denmark's Wind Energy Ecosystem

The development of wind turbines as new renewable energy source in the last 40 years is astonishing, from starting out in the 1970s with 10–30 kW turbines to, nowadays, giant turbines in our seas with rotor diameters of 160 m and capacities around 9.5 MW (Renewable Energy Agency 2018). However, the sticking point behind the development of the wind power energy is the levelized cost of electricity (LOCE), meaning the produced energy compared to the construction, production, installation, and O&M costs.

The technological evolution was hugely driven by the Danish wind power ecosystem. The relatively young industry has long benefited from the Danish hands-on R&D policy and the technical "smaller but safer" approach (Klaassen et al. 2005). A combination of elements made this possible: the public interest in energy source alternatives, investment subsidies, balanced and well-timed R&D, public procurement support, and last but not least, a focus on small reliable wind turbines lead to the strong innovation and diffusion of wind energy in Denmark. This approach generated better results than the ones of nearby big nations like Germany or the UK (Klaassen et al. 2005).

Drejer and Andersen divide the development of the Danish wind industry into a formative stage, a growth stage, and a globalization stage (Andersen and Drejer 2008). We use this classification to explain the chronological evolution of the Danish wind turbine ecosystem. However, we add a restructuration phase to the globalization stage to depict recent changes in light of new challenges and emerging technologies.

4.1 First Phase: Formative Stage: 1972–1980

The emergence of the modern Danish wind industry was triggered by the energy crisis and economic recession in the 1970s. Back then, a handful of wind energy idealists, enthusiastic amateurs, and entrepreneurs sparked interest in wind turbines as an alternative and freely available energy source. This small group of people collaborated closely to collectively achieving their goal of simply creating energy from the wind. Thereby, they took advantage of all the practical knowledge and experience they could gather. Their theoretical knowledge about wind turbines was still limited, yet they enjoyed success by practically testing new ideas and concepts. This is similar to what nowadays is described as a Fablab space with "makers" running experiments to develop new products (Mortara and Parisot 2017).

The early success attracted more and more players from the agriculture, machine, and boat industry (Andersen and Drejer 2008; Jensen 2003). This was different to most other countries which let large high-tech companies develop their big wind turbines completely, suggesting an entrepreneurial driven co-evolution dynamics between the promising technology and new applications (Giones and Brem 2017). The Danish approach proved to be more reliable and thus successful. Along the supply chain, small companies and entrepreneurs collaborated to jointly develop and build small wind turbines (Meyer 1995).

4.2 Second Phase: Growth Stage: 1980–2000

The second phase of the development of the Danish wind industry was initiated by the introduction of the Energy Plan, a subsidy-based program started in 1981. The reason was to reduce the dependency on energy imports. The plan supported wind energy producers by allowing them to feed energy into the power grid and to receive minimum (subsidized) prices for their production (Andersen and Drejer 2008). Shortly after, the main governmental support started shifting from manufacturers toward operators, in order to stimulate further market adoption of the new technology (Klaassen et al. 2005). This well-thought-out support program by the government, paired with the experience from a large number of installations, equipped the Danish manufactures with the first-mover advantage and gave them significant benefit over other companies (Smith 2011).

4.2.1 Building Trust and Legitimacy in an Emerging Industry

A key event in this private and public joint effort is the foundation of the Risø test station for wind energy research. The center, still now, connects scientific researchers with wind turbine manufacturers in Denmark. The Risø test center was known at that time for testing new designs and principles applying aerodynamic theory and putting them into practice (Andersen and Drejer 2008). With these steps, the development of wind turbines advanced from trial and error to a scientific and professional approach. With the majority of actors from the formation phase still involved, most of the learning took place through experimentation (Karnøe 1999).

The large demand for turbines in Denmark reflects the success of the Danish government incentive system. Besides the growing Danish market, an international market emerged for wind turbines which attracted new suppliers and manufactures. In addition to the increased demand, the request for bigger and more reliable turbines came up. These requests turned the wind turbine industry into a more complex and elaborated ecosystem. Danish actors tackled this problem by strengthening the collaboration among the main actors' supportive institutions, manufacturers, and suppliers.

The promising future of the wind industry attracted further suppliers from other industries and led to existing suppliers specializing solely in wind turbines. This additional knowledge from the supplier side boosted the development and amplified the supplier importance. In doing so, it highly increased the collaboration between manufacturers and suppliers.

4.2.2 Unusual Collaboration Arrangements with Suppliers and Competitors

Situations occurred where engineers from the supplier became temporary employees in the manufacturer's firm. Furthermore, cross-firm meetings and seminars with suppliers were hosted by supportive institutions. Even competitor collaboration could be seen if major breakdowns or problems occurred in the ecosystem. The tight collaboration was facilitated by the common goal of the main actors: boosting wind energy and showing its full potential (Andersen and Drejer 2008). Despite the high level of collaboration and co-creation, the manufacturers' supplier structure was almost flat; this had advantages but also caused two new problems in the industry: manufacturers received only parts without any system integration and suppliers were only allowed (through exclusivity agreements) to work with one of the main manufacturers (Megavind 2013).

4.3 Third Phase: Globalization Stage 2000–2006

The profound collaboration and collective technology development in the growth phase was strongly affected by new international directives and the new technical level wind energy had reached. The directive for liberalization of the European energy market, enacted 2001, allowed to trade electricity on the European energy market (Meyer and Koefoed 2003). Wind energy benefited from the directive; locally available wind electricity could be traded where it was in demand.

4.3.1 Park Developers as Innovation Intermediaries

Besides the reform, wind turbine technology reached the level at which energy generation became attractive for investors. At this point, investors started to promote large wind power parks, placing several wind turbines in a limited space. This new high-volume implementation could not be completely handled by turbine manufacturers and thus opened options for intermediaries. These were quickly taken up by park developers, which had tremendous consequences for the whole industry. Park developers quickly started to compete with manufacturers in park tenders, whereby developers came up with new competitive parameters and more successful business models with lower operation costs. This situation rearranged the supply system, in which wind turbine manufacturers now act as suppliers for wind park developers (Andersen and Drejer 2008).

This new structure also entailed a new business rivalry between wind turbine manufacturers that now compete to obtain tenders for a new park. The structural change caused a jolt through the whole ecosystem down to suppliers and dramatically increased the competition among all players. This jolt shifted focus more toward cost reduction and project success (Andersen and Drejer 2008).

4.3.2 Competition and Internationalization

Besides the new structural situation, a rapid international market growth occurred; it attracted foreign multinational corporations with huge financial force into the ecosystem [e.g., General Electric (GE)]. These circumstances finally initiated a series of rationalizations, buyouts, and mergers to stay competitive in the wind turbine market. Eventually the number of Danish wind turbine manufacturers radically decreased to Siemens (absorbing Danregn Vindkraft A/S and Bonus Energy A/S) and Vestas (absorbing NEG Micon A/S) as the main two players in the region (Andersen and Drejer 2008).

4.4 Fourth Phase: Restructuration Phase 2006–Present

The reduction of competitors was not enough to stay competitive on the marketplace for manufacturers. Both Siemens and Vestas had to restructure their supply chain in order to run their value chain leaner and more successful. The challenge for both companies was their still almost flat supplier structure in 2006 (Andersen and Drejer 2006). Suppliers mainly delivered their parts directly to the manufacturers, which caused additional organizational work for the manufacturers (Megavind 2013).

A major change happened in the supply chain in the ecosystem during the following 6 years. The flat supply chain transformed to a tier-based supply chain structure. The tier structure brought forth the introduction of the concept of "tier one" key suppliers (Andersen and Drejer 2012).

4.4.1 Changing to an Open Supply Chain Structure: Innovation for a Global Industry

This structural development of the ecosystem led to stronger research, development, and demonstration competence and cooperation across the value chain. Furthermore, it enabled sub-suppliers to deliver to different wind turbine manufacturers and strengthen the innovation in the whole ecosystem (Megavind 2013).

This evolution has brought the industry to rotor diameters of 160 m and capacities of 9.5 MW (Renewable Energy Agency 2018). Modern wind turbines are equipped with over 100 digital sensors, which transmit real-time data on the status of the turbine; they generate 2 gigabytes per day of data and open a myriad of opportunities to analyze and optimize turbine's operations.

5 A Value Chain View of Entrepreneurial Opportunities

We now take a step back to understand how new entrants have contributed to this successful evolution, how have new technologies been introduced, and what does this mean for digital technology entrepreneurs in the wind energy ecosystem.

5.1 One Industry but Different Maturity Levels

In their annual report of 2017, the Danish Wind Industry Association highlights that market demand during the last years has led to increasing industrialized production through standardization, regulatory requirements, and supply chain development, which are clear signs for maturity in industrial processes (Megavind 2017). Several of the actors we interviewed described the steps that the industry has done toward consolidation. Director 2 highlights this maturing process in saying that:

> [. . .] over all the most important thing that is happening is that the industry is getting more and more mature. With that I mean that the focus on driving down costs and doing things more and more standardized, you know consolidation of technological platforms, consolidation of manufacturers and suppliers (Director 2).

But, at the same time, the industry has new upcoming fields such as decommissioning and blade repair, which are in an early-stage phase. The Danish Wind Industry Association states in the same report that the industry is facing challenges when it comes to wind power plant life cycle, digitalization, and emerging markets. The new markets for wind power also introduce new conditions and challenges such as variety of climates, extreme weather, transport, or complex installations to name a few (Megavind 2017). The approach to these new challenges requires still an entrepreneurial mindset, as one of the expert researchers mentioned:

> Well it was less mature than now, it is maturing, but it is still a very, very, immature industry. Basically, they start-up again with every new farm; they start-up from scratch (Researcher 3).

5.2 A Substantial Barrier for New Entrants with Digital Technologies

The wind industry is a field where in most cases problems have already existing solutions; new entrants, consequently, have to verify and test their novel concepts considerably more, whereas start-ups in rather novel areas are able to bring their products to market with less certification and testing processes, and have much more room for experimentation as it often happens with new technologies (Woolley 2014; Giones and Brem 2017). As the CEO of a service and transport company mentions:

> I would not start [his company] today, I think that would be almost impossible, but when we started [his company], there was basically a gap [. . .] it was not that I had years of experience, but nobody had (years of experience) at that time [. . .] but there a still new niches where nobody has started a company. I mean, we could start another company. . . (Director 1).

A more detailed analysis of the interviews suggests that actually the opportunities for new entrants have different characteristics, and entry barriers, depending on whether they fall in the development or operations part of the industry value chain.

5.3 The Value Chain Structure Determines the Gaps for New Entrants

The value chain for the industry in Denmark is described in Fig. 1. From left to right, it starts with sub-supplier and system supplier, which deliver to wind turbine

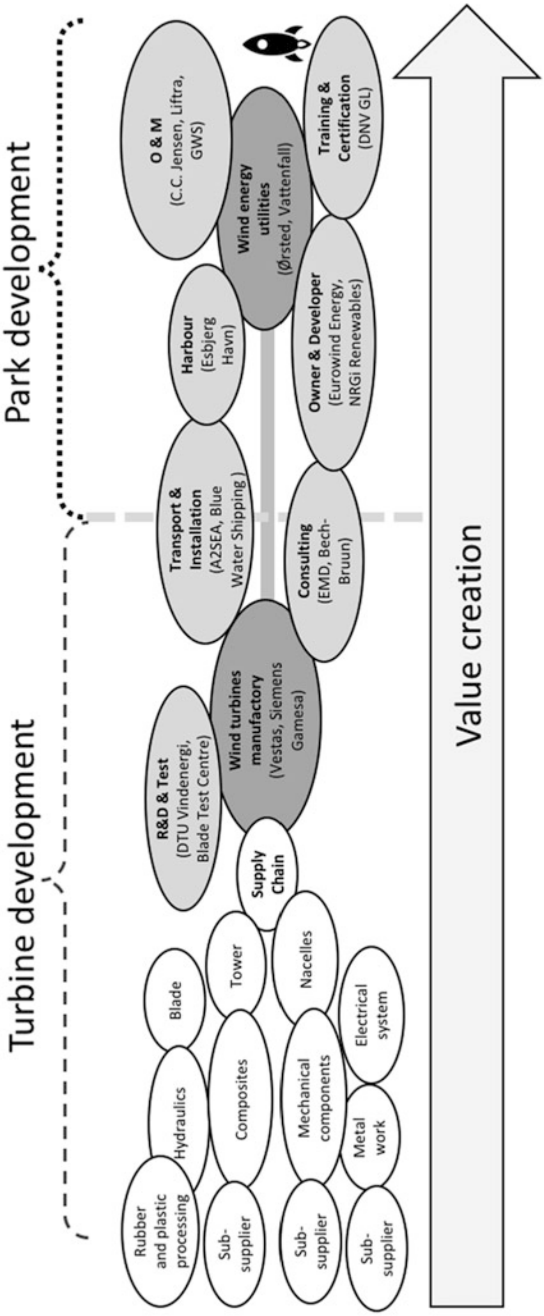

Fig. 1 Value chain of the Danish wind industry with company examples from the Danish Wind Industry Association (Danish Wind Industry Association 2017). Source: authors' own figure

manufacturers. Research and test institutions contribute to turbine development, as well. After the turbine development activities, the next major actors in the value chain are the wind energy utilities, which tender new wind parks. To build these parks, actors in transportation, installation, and consulting are required in the value chain. Local harbors facilitate the transport process from onshore to the off-shore park location and park owners monitor the process. The successful operation and maintenance of wind turbines through appropriated training and certification is the final step in the value chain (Danish Wind Industry Association 2017; Megavind 2013). The rocket icon on the right-hand side depicts the area, where we found most entrepreneurs entering into the industry value chain. Furthermore, most interviewees see this area in the value chain as highly attractive for the introduction of new digital technologies.

5.3.1 Three Major Barriers and a Surprise for New Entrants in the Turbine Development Activities

Interestingly, for an industry that historically thrived on collaboration between researchers and competitors, the development phase of their products has now become a closed process. Three major barriers have emerged for new entrants, in particular if they are completely new companies with limited resources or experience in other industrial fields.

First, there is a lack of information on where digital and non-digital innovation is needed. One interviewee highlighted this fact as follows:

> There are so many things (innovation challenges for wind turbines). The problem in all this is to identify them, and actually also for the wind turbine manufacturers to communicate them, because a part of communicating an innovation challenge includes to reveal your technology. They (innovation challenges) can be discussed when you are together with them (manufacturers) and know them, but they are not putting them out (Researcher 1).

Second, the high and mature technological level of the turbine development requires more experience and advanced research resulting in higher development costs. Additionally, as turbine development happens at the beginning of the value chain, its technological innovations strongly impact companies located in other areas of the value chain. Take for example, mechanical improvements on the nacelle's design; these changes may require new arrangement of components inside of the nacelle, adaptions of transport vehicles, adapted lifting equipment, and lastly, training of installation and service personnel. The turbine development impacts many actors and the innovations have to be coordinated across the value chain. Hence, changes in the turbine development have to be well thought out, as wind turbines have tremendous investment cost and long lifetimes. As an experienced engineer in the Danish Wind Industry Association described:

> If you take for instance the aviation industry. The blades are almost like a wing from an aero plan and the numbers are very similar to the aircraft industry. Bringing in huge components from all over the world. [. . .] when it (Wind turbine) doesn't run it costs a lot of money, but it doesn't cost lives as it does in an aircraft. But a machinery which is going to manufacture

> around 100.000 hours in its lifetime. It is very critical, it has to be very well regulated, very well controlled, and very well described. So, you have to learn a little bit from critical industries, as well (Engineer 2).

These conditions force new entrants introducing innovations in turbine development to include high warranties to cover breakdown risks. This adds financial stress to the new entrants:

> Projects get bigger and bigger [. . .] You need to have more funds, because let's say 10 years ago you could put up a warranty for let's say 5 million dollars, that would be ok. But now, you need to put up like 30 maybe 50 maybe 100 million dollars, before they let you in, they need to be sure that if anything happens you can pay (Researcher 3).

Third, the industry life cycle (Klepper 1997) determines the opportunity window for new digital innovations. Turbine developers only change their development platforms for a new turbine after several years when there are enough potential innovation gains that make it worth changing the whole platform. These circumstances put extra pressure on the new entrants exploring the potential of a new technological innovation; the entrepreneur has to pace their tech development to the opportunity window in the industry. As an expert researcher described:

> They are not thinking long-term. They are only thinking one project at a time, because they do not know if they get the next projects, so why invest time and resources in better collaboration, better interface management and so on (Researcher 3).

Additionally, for successful market entry, new suppliers have to either address an urgent need caused by an unexpected problem in the industry or synchronize their solution with a new generation that uses a different manufacturing platform. The interview with the Danish Wind Industry Association highlights the importance of this issue:

> You have to have the first customer who is going to pay for the product and make the test [. . .] So there has to be a problem or you have to offer your product when they start with a new manufacturing platform (Engineer 2).

Contrary to our expectations, the degree of digital innovation in turbine development and manufacturing seems to be rather low. This is explained by the focus on increasing the power generated by wind turbines, instead of aiming for efficiency gains with digital technologies. In this sense, the wind industry could be another context where digital entrepreneurs could replicate successes in other similar industries such as the automotive industry (Woolley 2010). But this is not happening yet. As one of the researchers pointed out:

> When you talk about manufacturing in Siemens and Vestas, then it (the digital innovation of manufacturers) will be like any other business in the production side and I don't think that will be much different than Grundfos and Danfoss and other industrial manufacturers (Researcher 3).

5.3.2 Opportunities in the Operation and Maintenance Activities of the Value Chain

While there is limited entrepreneurial activity in turbine development, it is actually downstream the value chain where we see more activity. In the "park development" activities described in Fig. 1, there have been several new entrants, as reported by one of the experts in the field:

> They (turbine manufacturers) do not want to take any risk. I think that is a barrier for new developers, especially if it is (related to) technology. It is easier (to enter) in the operations, service and maintenance areas (Researcher 3).

The park development fundamentally consists of services-related work. Service activities have fewer risks than turbine development; in case of errors you only have to bear with the running costs of the services. The service and maintenance activities have seen more new players than the turbine development activities. Engineer 2 points out that:

> It is very much depending on what do you bring in the market, it is typically in operation and maintenance where they grow fast. Growth is very (dependent on) the industry. It is typically (related to) the main components, when you supply control systems you grow with your customer. But [. . .] exponential growth [. . .] is related to manpower, that means operation and maintenances, it is related to (introducing) disruptive technology (Engineer 2).

The term of disruptive technologies is used as a synonym for digital technologies, as they are capable of restructuring the service and maintenance work by making manpower partly redundant and allow for new business models. Furthermore, the field of innovation of park development is more clearly defined than the non-visible innovation challenges in turbine development. According to several industry sources, 50% of the operating expenditures are caused by unscheduled maintenance. This fact is well known and energy utilities nudge for innovation to reduce this number as soon as possible.

5.3.3 Where Did New Entrants Go in the Wind Industry?

The search on start-ups within the Danish wind industry, using information registered at the large start-up repository Crunchbase (crunchbase.com), gives evidence of the limited number of new entrants in the industry in the last 10 years. It is quite significant that 8 out of the 10 founded start-ups are working within the operation and maintenance area, as Table 2 shows.

Companies in operation and maintenance have also understood that digital innovation can bring new game-changing solutions that can reduce costs, downtimes, and risk. The Danish Wind Industry Association believes that digitalization is capable of bringing up new ways for rethinking the life cycle of wind energy parks. Thereby, a complex web of data should connect planning, design, manufacturing, transportation, operation, maintenance, and decommission (Megavind 2017; Brink et al. 2016).

Actors in the industry are aware of the data collection easiness using digital technologies; however, the perception is that the human experience is still required to analyze the data output. Director 2 argues that:

> You still need to do an evaluation of what has been filmed by the drone and you have to decide on the action that has to be done (Director 2).

Further challenges are seen to make the most of big data or artificial intelligence solutions for the industry. For example, the problem of comparability of data emerged:

> the digital part, of course, plays a role, at the moment it is apples and bananas because you have a lot of data, but it is from different wind turbines, it is from different turbine sizes. So, you have a lot of data which is not comparable, because the wind turbine has grown in size and different types and whatever. So, it is limited how much you can utilize the data (Researcher 2).

5.4 The Future of the Industrial Innovation Ecosystem

The predominant position of Denmark as a wind energy hub has changed over the last 20 years. Interviews revealed that the wind energy ecosystem in Denmark is not a key global gatekeeper for new entrants. We expected that regional proximity would be a key factor to attract entrepreneurs and innovation to the industry (Boschma 2005). But the wind energy industry is demand driven, meaning their sites and actors are always moving to the geographic location where "*the support machine is running*" (Director 2). Furthermore, the pioneer's positions are lying rather with the Danes and their knowledge than in the region, as they keep their positions at the top of the leading companies. Researcher 2 adds that:

> It (the advantage) is that they still have the education, the training and the network going on and the Danish people are very good at that (Researcher 2).

Therefore, it appears that the knowledge that has contributed to build the innovation ecosystem is much more movable than we would have expected; this would suggest a close dependence between where the knowledge is rewarded and where growth and strategic renewal occur (Agarwal et al. 2010).

Nevertheless, the localized social and human capital still has a big influence on the successful entry of new entrants. We use the case of one of the companies' interviews to illustrate how digital technology entrepreneurs interact with the established industrial ecosystem. The company (name not disclosed due to anonymity request) is developing a new digital service solution for wind turbines using a robotic aid. Both cofounders are very experienced as they have worked in the wind industry for several years (thus we are in a knowledge spillover situation). They are well aware of the entrance barriers that are prevailing in the ecosystem. As a safety, both cofounders agreed on three milestones, which had to be achieved before they would establish the company and further develop their technology: (1) a proof of technological feasibility, (2) a first customer, and (3) financial support. These three milestones also reflect the entry barriers, which were described by other interviewees. It was only after overcoming each of these milestones that the cofounders officially started their successful company:

> I would like to say we had three milestones we needed to accomplish before we could start the company [. . .] The first thing was that we ourselves wanted to belief in the technology before working [. . .] So, step number one was we needed to test the technology or subcomponents of the technology to an extent where we belief ourselves that it could be done. Step number two were to get a player in the market to belief in the product to an extent where they were willing to allow us to test on the product free of charge. [. . .] somebody else also need to belief in the product, that either be a wind turbine owner or a windfarm producer [. . .]. The third one, we wanted that somebody who thinks commercially (with a business mindset) should also believe in it. This was formulated as somebody else also needed to put in some money into the project (Director 3).

As a result, we see how the industry consolidation has also affected the entry strategies in the downstream operations of the value chain. On the other hand, the core technology development activities related to the new wind turbines have been kept in-house and subject to an increasing pressure with shorter development times and lower overall production costs.

While the turbine development activities are still the most knowledge-intensive activities, the areas where new digital technologies are having a stronger presence, as well as new entrants, is in the last activities in the value creation process. The challenge for the industrial ecosystem in the Danish region is that these last activities are mostly performed where the wind turbines are installed and maintained, making them more likely to be offered by local players.

6 Implications for Research and Practice

Going back to our starting point, we expected to see an interaction between the digital technologies entrepreneurial ecosystem and the wind industry innovation ecosystem that could contribute to the present and future growth of the industry in Denmark. What we have observed instead is an industry that is closing part of its value chain and shifting toward global competition. Instead of seeing a process of strategic entrepreneurship by the leading actors in the ecosystem, what our results suggest is that they have sustained their focus on the technology development leaving open the operation and service areas of their products.

In our research, we have observed that while the entry barriers have reduced the number of new competitors in the turbine development, it has also made it a more cost-driven market. It has been in park development and maintenance where entrepreneurs (as new entrants) with novel technological solutions have found opportunities to introduce digital and non-digital innovations and start servicing customers.

Furthermore, several of the data sources we have reviewed suggest that the shift toward a service orientation could be the main driver of growth in the whole wind energy industry in Denmark. As one of the expert researchers in the industry mentioned:

> If we look at Vestas, their services business is increasing rapidly and so is Siemens', because, think about it, in a decade or so we will not need any new projects, we only need to reinstall power plants, therefore we will see (more often) the business case of the service provider (Researcher 3).

However, an improvement of wind parks also implies a development of the turbine technology in order to reduce breakdowns and increase efficiency or services related to the decommissioning of the park. This will have an impact on the mix of products and services of the industrial players in the region.

6.1 Keeping the Innovation and Entrepreneurship in the Region

In practical terms, our findings suggest the need to act in order to stimulate digital innovation in the industry. To improve the innovation dynamics for turbine development, the current high entrance barriers, including funding and testing, should decrease. Advanced research and test facilities in the innovation ecosystem could lower entrance barriers, where new digital technology innovations could be tested and developed on major platforms to attract clients more easily. This could be similar to concepts being put in practice in emerging industries, where entrepreneurs can test new technology applications in testbeds (Mulgan 2017); such arrangements also support the different maturity levels (including standards and regulation) required for innovative experimentation and industrialized production.

A concerning finding is that the region that has benefited the most during the emergence of the industry might not be able to keep a relevant position in the future. Our results show that the industry location is rather demand driven, "*due to scale we (Denmark) cannot be in the forefront anymore*" (Researcher 3), as other regions will come up with much higher wind energy demand prospects (both onshore and offshore). Therefore, it is important to strengthen the research and development of wind turbines, so major wind turbine actors keep their main research and development actives in the Danish innovation ecosystem. In other words:

> I think Denmark could still be the hub and the pioneer due to [the fact] that we have Vestas and Siemens. But the issue for Denmark is that we are not so big, so we cannot install so many power plants (Researcher 3).

A valuable insight for innovation policy makers and institutions in the region is that the connection between digital technologies entrepreneurs and the industrial ecosystem does not occur automatically. Our findings suggest the need for intermediaries that facilitate the connection between researchers, entrepreneurs, and established industrial players (Howells 2006; Clayton et al. 2018). We have seen some positive anomalies, for example, the case of Vaavud, a crowdsourced weather service, which aims to provide valuable insights for the wind turbine operators, but these have been isolated success cases instead of a continuum of new spin-offs or start-ups.

In a nutshell, the entrepreneurial ecosystem for digital innovation in wind energy has the potential to increase to the level it has reached in other industries, but this might only happen if the knowledge is rewarded, if entrepreneurs' experiment with new technological applications, and if intermediaries facilitate the connection between the emerging and consolidated ecosystems.

7 Limitations and Further Research

Our results open the door to further research streams on the topic and are not absent of several limitations. First, we have been exploring a rather emergent phenomenon; only now the large industrial players are starting to adopt drones, AI, IoT, VR, or Blockchain or other digital technologies. Plus, some of these activities are conducted in secrecy as they are seen as future competitiveness levers. Therefore, the low levels of activity observed can be attributed to the phenomenon being still at an early stage. It will be important to revise, with a longitudinal view, how it evolves in the coming years as digital technologies are introduced in more mature industries that generate use cases that stimulate more entrepreneurs and increase interest across the Danish wind energy ecosystem.

Second, we tapped on the growing literature on entrepreneurial and innovation ecosystems; our results suggest that there are further opportunities in this field. For example, we could only identify that the ecosystem evolution shifted as the industry consolidated, and it actually almost split into two separate innovation ecosystems: turbine manufacturing and wind park development and maintenance. This had implications for new entrants and for the innovation dynamics; this promises to be an interesting research area to analyze and theorize on the evolution and development of innovation ecosystems, for instance, reconnecting ecosystems with biology evolution theories (McMullen 2018).

Finally, this research opens up further interesting opportunities to study how innovation ecosystems mature and when (and how) they benefit from the activity in emerging entrepreneurial ecosystems in the region. We could only report on a short historical account and recent entrants introducing digital technologies. This is an area that needs further research, as it promises to hold valuable insights for innovation policy makers and industrial players that want to contribute to their region's growth and development.

References

Adner, R., & Kapoor, R. (2010). Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations. *Strategic Management Journal, 31*(3), 306–333.

Agarwal, R., Audretsch, D., & Sarkar, M. (2010). Knowledge spillovers and strategic entrepreneurship. *Strategic Entrepreneurship Journal, 4*(4), 271–283.

Andersen, P. H., & Drejer, I. (2006). *Danmark som wind power hub – mellem virkelighed og mulighed*. København: Vindmølleindustrien.
Andersen, P. H., & Drejer, I. (2008). Systemic innovation in a distributed network: The case of Danish wind turbines, 1972–2007. *Strategic Organization, 6*(1), 13–46.
Andersen, P. H., & Drejer, I. (2009). Together we share? Competitive and collaborative supplier interests in product development. *Technovation, 29*(10), 690–703.
Andersen, P. H., & Drejer, I. (2012). *Denmark – The wind power hub: Transforming the supply chain*. København: Vindmølleindustrien.
Autio, E., Nambisan, S., & Thomas, L. D. W. (2018). Digital affordances, spatial affordances, and the genesis of entrepreneurial ecosystems. *Strategic Entrepreneurship Journal, 12*(1), 72–95.
Boschma, R. (2005). Proximity and innovation: A critical assessment. *Regional Studies, 39*(1), 61–74.
Brink, T., & Madsen, S. O. (2016). The triple helix frame for small- and medium-sized enterprises for innovation and development of offshore wind energy. *Triple Helix, 3*(1), 4.
Brink, T., Ole Madsen, S., & Lutz, S. (2016). *Perspectives on how operation & maintenance (O&M) innovations contribute to the reduction of Levelized Cost of Energy (LCOE) in offshore wind parks*. https://doi.org/10.13140/RG.2.1.1860.2640.
Brown, R., & Mason, C. (2014). Inside the high-tech black box: A critique of technology entrepreneurship policy. *Technovation, 34*(12), 773–784.
Clayton, P., Feldman, M., & Lowe, N. (2018). Behind the scenes: Intermediary organizations that facilitate science commercialization through entrepreneurship. *The Academy of Management Perspectives, 32*(1), 104–124.
Cohen, B., Amorós, J. E., & Lundy, L. (2017). The generative potential of emerging technology to support startups and new ecosystems. *Business Horizons, 60*(6), 741–745.
Colombelli, A., Krafft, J., & Quatraro, F. (2014). The emergence of new technology-based sectors in European regions: A proximity-based analysis of nanotechnology. *Research Policy, 43*(10), 1681–1696.
Danish Wind Industry Association. (2017). *The green pages*. København.
Dedehayir, O., Mäkinen, S. J., & Ortt, J. R. (2016). Roles during innovation ecosystem genesis: A literature review. *Technological Forecasting and Social Change.*
Eisenhardt, K. M. (1989). Building theories from case study research published by: Academy of Management Stable (Linked references are available on JSTOR for this article: Building Theories from Case Study Research, 14(4), 532–550). http://www.jstor.org/stable/258557
Eisenhardt, K. M., & Graebner, M. (2007). Theory building from cases: Opportunities and challenges. *Academy of Management Journal, 50*(1), 25–32.
Flyvbjerg, B. (2004). *Five misunderstandings about case-study research* (pp. 420–434). *Practice*.
Giones, F., & Brem, A. (2017). From toys to tools: The co-evolution of technological and entrepreneurial developments in the drone industry. *Business Horizons, 60*(6), 875–884.
Howells, J. (2006). Intermediation and the role of intermediaries in innovation. *Research Policy, 35* (5), 715–728.
Jensen, I. K. (2003). *Mænd i modvind:et dansk industrieventyr*. København: Børsens Forlag.
Karnøe, P. (1999). When low-tech becomes high-tech: The social construction of technological learning processes in the Danish and the American Wind Turbine Industry. In *Mobilizing resources and generating competencies: The remarkable success of small and medium-sized enterprises in the danish business system* (pp. 85–139). Copenhagen: Copenhagen Business School Press.
Klaassen, G., et al. (2005). The impact of R&D on innovation for wind energy in Denmark, Germany and the United Kingdom. *Ecological Economics, 54*(2–3), 227–240.
Klepper, S. (1997). Industry life cycles. *Industrial and Corporate Change, 6*(1), 145.
Leech, N. L., & Onwuegbuzie, A. J. (2007). An array of qualitative data analysis tools: A call for data analysis triangulation. *School Psychology Quarterly, 22*(4), 557–584.
Li, L. (2013). Technology designed to combat fakes in the global supply chain. *Business Horizons, 56*(2), 167–177.

Lucas, H. C., & Goh, J. M. (2009). Disruptive technology: How Kodak missed the digital photography revolution. *Journal of Strategic Information Systems, 18*(1), 46–55.

McMullen, J. S. (2018, June). Organizational hybrids as biological hybrids: Insights for research on the relationship between social enterprise and the entrepreneurial ecosystem. *Journal of Business Venturing, 33*, 1–16.

Megavind. (2013). *The Danish wind power hub*. København.

Megavind. (2017). *Annual research and innovation agenda*. København.

Meyer, N. I. (1995). Danish wind power development. *Energy for Sustainable Development, 2*(1), 18–25.

Meyer, N. I., & Koefoed, A. L. (2003). Danish energy reform: Policy implications for renewables. *Energy Policy, 31*(7), 597–607.

Mortara, L., & Parisot, N. (2017). How do Fab-spaces enable entrepreneurship ? Case studies of "Makers" – entrepreneurs. *International Journal of Manufacturing Technology and Management, 32*, 16–42.

Mulgan, G. (2017). Anticipatory regulation: How can regulators keep up with fast-changing industries? *NESTA Blog*.

Nambisan, S., & Baron, R. A. (2013). Entrepreneurship in innovation ecosystems: Entrepreneurs' self-regulatory processes and their implications for new venture success. *Entrepreneurship Theory and Practice, 37*(5), 1071–1097.

Oh, D. S., Phillips, F., Park, S., & Lee, E. (2016). Innovation ecosystems: A critical examination. *Technovation, 54*, 1–6.

PwC. (2016). *Clarity from above. PwC global report on the commercial applications of drone technology*. Warsaw: PwC.

Ravenswood, K. (2011). Eisenhardt's impact on theory in case study research. *Journal of Business Research, 64*(7), 680–686.

Renewable Energy Agency, I. (2018). *Renewable power generation costs in 2017*.

Ritala, P., & Almpanopoulou, A. (2017). In defense of 'eco' in innovation ecosystem. *Technovation, 60–61*, 39–42.

Robinson, O. C. (2014). Sampling in interview-based qualitative research: A theoretical and practical guide. *Qualitative Research in Psychology, 11*(1), 25–41.

Scaringella, L., & Radziwon, A. (2017). Innovation, entrepreneurial, knowledge, and business ecosystems: Old wine in new bottles? *Technological Forecasting and Social Change*, 0–1 (December 2015).

Simmie, J. (2012). Path dependence and new technological path creation in the Danish wind power industry. *European Planning Studies, 20*(5), 753–772.

Smith, K. (2011). The Danish wind industry 1980–2010: Lessons for the British marine energy industry. *Underwater Technology, 30*(1), 27–33.

Spigel, B. (2017). The relational organization of entrepreneurial ecosystems. *Entrepreneurship Theory and Practice, 41*(1), 49–72.

Stam, E. (2015). Entrepreneurial ecosystems and regional policy: A sympathetic critique. *European Planning Studies, 23*(9), 1759–1769.

Thomas, L., Sharapov, D., & Autio, E. (2017). Linking entrepreneurial and innovation ecosystems: The case of appcampus. In G. Alvarez, S. Carayannis, E. G. Dagnino, & R. Faraci (Eds.), *Entrepreneurial ecosystems and the diffusion of startups* (p. 208). Cheltenham, UK: Edward Elgar.

Woolley, J. L. (2010). Technology emergence through entrepreneurship across multiple industries. *Strategic Entrepreneurship Journal, 4*(1), 1–21.

Woolley, J. L. (2014). The creation and configuration of infrastructure for entrepreneurship in emerging domains of activity. *Entrepreneurship Theory and Practice, 38*(4), 721–747.

Zhang, W., & White, S. (2016). Overcoming the liability of newness: Entrepreneurial action and the emergence of China's private solar photovoltaic firms. *Research Policy, 45*(3), 604–617.

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