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From Industry 4.0 to sustainable innovation ecosystems 4.0: what challenges for the innovation intermediaries?

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Executive summary

What does “innovation ecosystem 4.0” really mean, particularly for key actors of innovation ecosystems such as innovation intermediaries? We assume that the public innovation intermediaries will have to take into account the sustainable perspective and reconsider their key missions in networking and in transferring knowledge and technology. After the identification of the new challenges due to some tensions between the implementation of the 4th revolution (Industry 4.0) and the operationalization of circular economy principles, we have chosen to investigate them, through the public intermediary organization, called Fil’innov, created in 2014 by the University of Nantes (West of France). Given its missions and central position within the innovation ecosystem, Fil’Innov has a major role to play, by orienting and supporting actors towards more sustainable innovation ecosystems. We use a Business Model approach to find out the first steps to promote this orientation towards the sustainable innovation ecosystem, “the Innovation ecosystem 4.0”.

Introduction

“Innovation Ecosystems” is a concept, still ambitious and non-stabilized, that embraces several approaches (STPs, Innovation Districts, Areas of Innovation, etc.). The emerging concept of innovation ecosystem 4.0, in this beginning of the 21st century, can also be seen as a concept in vogue or a container concept. What does “innovation ecosystem 4.0” really mean, particularly for key actors of innovation ecosystems such as innovation intermediaries?

We consider that this concept has to be investigated through a double perspective shaped by two current basic trends: the 4th Industrial Revolution, on the one hand, and the circular economy on the other hand.

Companies, universities or higher education institutions, institutional actors, and local authorities have confirmed, over the past decade, their commitment to innovation ecosystems in order to develop their territories in a globalized economy but the step toward innovation ecosystem 4.0. remains undocumented. New collaboration arrangements, between academic and industrial spheres, have emerged, with the development of intermediation activities (Alexander & Martin, 2013; Howells, 2006), to strengthen the firms capacity to innovate (Kaufmann & Tödting, 2001). Intermediaries can be public, private or hybrid structures (Champenois & Etzkowitz, 2018). They can be formal organizations or virtual platforms (Adner, 2017; Parker, Halgin, and Borgatti, 2016). Regardless the arrangements, these intermediaries have not, up to now, tackled the sustainable and

revolutionary issues simultaneously. Does it mean that new activities, approaches, managerial tools will have to be designed by these innovation intermediaries? If recent work has focused on the role of innovation intermediaries and has clarified the main issues they have to face (Landry, Amara, Cloutier, & Halilem, 2013), little research has been done on the role of intermediary organizations – particularly the public structures - in this transition process towards sustainable innovation ecosystems 4.0.

In this article, we assume that the public innovation intermediaries will have to take into account the sustainable perspective and then to reconsider their key missions in networking and in transferring knowledge and technology. They will have to confront major and often new challenges due to some tensions that will occur between the implementation of the 4th revolution (Industry 4.0) and the operationalization of circular economy principles. We have chosen to investigate these tensions, through a longitudinal study of an intermediary organization, called Fil’Innov. Fil’Innov was created in 2014 by the University of Nantes (West of France), a large and pluridisciplinary university willing to assert its position in the regional innovation ecosystem. For our purpose, we have designed a specific framework interplaying the main features of the 4th industrial revolution and business modeling

Our paper aims to answer the following questions: what are the challenges a public intermediary organization has to face to become a leading actor in innovation ecosystems 4.0? To what extent the Business Model (BM) approach would be relevant to find out transition trajectories to develop sustainable and innovative ecosystems? Our aim is threefold: (i) empirical: to propose visual and efficient tools to be able to share and discuss the possible evolution of intermediary organizations and innovation ecosystems towards a more sustainable development through the 4th Industrial (R)evolution (ii) theoretical: to question through a multi-level approach the intermediation activities and the support innovation ecosystem to set up (iii) practical: to contribute to empower the intermediary organizations’ managers and policy makers involved in innovation ecosystems 4.0.

The paper is organized as follows: section 1 presents the tensions between the 4th industrial revolution and the circular economy in order to clarify the challenges met by public intermediary organizations. In section 2, we present our case “Fil’Innov” and our methodology. In section 3, in order to address the tensions, we propose a specific theoretical framework based on a literature review, interplaying the main features of the Industry 4.0 technologies, the ecosystem modelling, and the business model perspective. In section 4, we discuss how intermediary organizations could introduce new tools to support this transition phase towards sustainable innovation ecosystems.

1. 4th Revolution and circular economy: tensions and challenges

Industry 4.0 is still an emerging and non-consensual concept and there is no clear vision about this new manufacturing paradigm, regarding its implications and consequences (Pereira & Romero, 2017). We consider that it is not a fourth revolution but rather the accelerating and intensifying extension of the industrial trajectory at least since the mid-20th century. As this trajectory is not sustainable our quest is to identify the major tensions and challenges for curving the trajectory in order to really tackle the urgent problems of the 21st century.

1.1. Beyond the concept of Industry 4.0

The concept of Industry 4.0 emerged in Germany in 2011 and then has spread, during the 2010s, in the USA, in Europe and in Asia thanks to the support of national government plans (Liao et al., 2017). Lu (2017, p. 3) summarizes Industry 4.0 “ as an integrated, adapted, optimized, service-oriented, and interoperable manufacturing process which is correlate with algorithms, big data, and high technologies.” The goal of Industry 4.0 is to maximize the productivity and to achieve a high level of operational-, resource-, cost-, and time-efficiency. Flexible production and quick adaptation to the customers’ requirements are made possible with a close integration of highly automated processes and information technologies and networks.

Despite its worldwide success, the concept of Industry 4.0 seems to be problematic to us. First, it remains non-consensual or ill defined (Pereira & Romero, 2017) as so far it has no unanimously adopted definition (Lu, 2017). Second, the term Industry 4.0 stands for the fourth industrial revolution. According to Liao et al. (2017), the earliest presentation of ‘The fourth industrial revolution’ traces back to 1988 with a paper of Rostow. The fourth industrial revolution is commonly accepted now and claimed by many authors (Kagermann, 2015; Lu, 2017; Kamble et al., 2018; Vaidya et al., 2018) but we deny the word revolution for several reasons. One reason is that there is no universal agreement on what is an industrial revolution (Liao et al., 2017). For authors such as Rifkin (2011), we are in the third industrial revolution. A second reason is that Industry 4.0 is still in a conceptual state (Pereira & Romero, 2017) or is a visionary although realistic concept (Vaidya et al., 2018). As such it is more present in academic debates than in industrial reality. A third reason to be cautious with the so-called fourth industrial revolution is that it addresses mainly the traditional criteria of performance in effect during the 20th century (economic growth, increasing productivity and profits, time and costs continuous reduction) but largely ignores or does not seriously tackle major challenges of the 21st century such as non renewable resource depletion, proliferation of waste, loss of biodiversity, climate change, etc.

1.2. Industry 4.0 and Sustainable Economy: the identification of major tensions

The rare studies claiming that Industry 4.0 will be sustainable, included in its environmental and social dimensions, are often too thinly substantiated to be really convincing (Braccini & Margherita, 2019). Furthermore, several theoretical and practical gaps remain that make difficult to establish the balance between benefits and drawbacks. Industry 4.0 is expected to reduce costs of manufacturing through end-to-end digital integration but its implementation will require huge amount of investment and there is no literature to demonstrate its economic sustainability (Liao et al., 2017; Kamble et al., 2018; Vaidya et al., 2018). If the prevailing system of production and consumption, mainly organized under the linear economy principle “take-make-dispose”, is no longer sustainable (Ghisellini et al., 2016), the literature generally considers that digitization in smart factories will allow Industry 4.0 to reduce overproduction, production waste, and energy consumption resulting in sustainable green practices. However, the smart production system, with its numerous high-tech equipments, is also intensive in resource and energy requirements that lead to negative environmental impacts (Kamble et al., 2018; Tseng et al., 2018). Between better improved efficiency and additional resource and energy consumption, the benefits in terms of environmental impacts remain to be demonstrated (Kagermann, Wahlster, and Helbig 2013).

Strategies such as 3R principles (Reduction, Reuse, Recycle) (Su et al., 2013) seem to be ignored by the literature on Industry 4.0 as well as the use of secondary raw materials. Industry 4.0 is considered as having an enormous potential for realizing sustainable industrial value creation in social dimensions because automation and digitization, for example, allow workers to operate in safer manufacturing environments than in the traditional industries (Kamble et al., 2018). Human workers are expected to play an important role in performing the production in Industry 4.0 contrarily with Computer Integrated Manufacturing (Vaidya et al., 2018). Nevertheless, the integration of Industry 4.0 in manufacturing systems may have a massive impact on labor market, professional roles, job profiles, as well as on management and organization (Pereira & Romero, 2017; Braccini & Margherita, 2019).

Concerning the supply chain management, disruptive changes may be brought by Industry 4.0 (Lu, 2017) because rich data will be available in real time from everywhere in the value chain (Kamble et al., 2018). Digitization should then be a key enabler of a reliable future transport system and supply of goods (Kagermann, 2015). Nevertheless, network reconfiguration and reverse-supply chain management remain rather unexplored areas (Lieder & Rashid, 2016). This is the reason why future studies on the impact of smart manufacturing on supply chain networks, reverse logistics, product recycling and remanufacturing are required (Kamble et al., 2018).

The tensions identified above demonstrate that the implementation of Industry 4.0 will require strategic management research efforts, particularly to study its sustainability (Liao et al., 2017) and the interaction of BMs in the whole value chain (Kagermann, 2015; Lu, 2017). These researches could advantageously be carried out under the “umbrella concept” of circular economy (Blomsma & Brennan, 2017). In fact, circular economy is considered either as a concept to supersede sustainable development or to operationalize it (Kirchherr et al., 2017; Merli et al., 2018). Furthermore, global reverse networks management and new BMs are two important building blocks to the transition to a circular economy (Planing, 2015).

The current logic of Industry 4.0 is to optimize the efficiency of the whole value chain, with the support of digital technologies, while keeping traditional criteria of performance. To explore sustainability and circularity issues in all their dimensions, we assume that Industries 4.0 promoters could benefit from the support of innovation or transition intermediaries (Howells, 2006; Kivimaa, 2014) to move from value chain optimization to ecosystem modeling. These intermediaries could help to design innovative BMs in terms of sustainability or circularity (Stubbs & Cocklin, 2008; Antikainen & Valkokari, 2016; Linder & Willander, 2017). These initial findings guide us towards our theoretical choices for analyzing our case study.

2. Methodology and theoretical framework

Before presenting our theoretical framework to address the tensions mentioned above, we briefly describe our context and case study Fil’Innov, a public intermediary organization created by the French multidisciplinary University of Nantes.

2.1. Context and case study: Fil’Innov, an intermediary organization

Fil’Innov is part of the innovation policy initiated by the University of Nantes a few years ago. Since the early 2000s, French policymakers have heavily developed investments and facilities to foster innovation and sustain collaborations and transfers between universities and firms. In this context, public-private collaborations were encouraged (e.g. through tax incentives) but had been reported to be insufficient. Nowadays universities are becoming actors in innovation networks by occupying an increasingly central position in their innovation ecosystem. The French multidisciplinary University of Nantes decided in recent years to reclaim the technology transfer mission, as specified by the law. Our study focuses on the regional innovation ecosystem around the city of Nantes and more specifically on the organization called “Fil’innov” developed by the University of Nantes (UN) since 2014.

Fil’innov is a new service, established in the UN Innovation Management Service, offering knowledge and competencies mapping the UN laboratories as well as personalized information, connections and follow-up for innovative collaborative projects between the university and the firms. The service is structured in nine sectors corresponding to the main industries of the area (such as Health & Biotechnology, Energy, Mechanics, Materials, Civil Engineering, Fishing, etc.). It is meant to be complementary to the other actors of the innovation ecosystem, claiming the “compass” mission in a complex environment.

Given its missions and central position between a large number of actors within the ecosystem, we consider that Fil’Innov has a major role to play. It can develop a complementary mission in orienting and supporting actors towards more sustainable innovation ecosystems by promoting alternative behaviors and new BMs.

2.2. Data collection

Through longitudinal research and support approach (Bréchet, Émin, and Schieb-Bienfait, 2014) we got involved in the Fil’Innov project and its ecosystem through different seminars and meetings. This posture has enabled us to establish and maintain regular relations with the actors, while preserving an external perspective. Far from a sponsor-to-provider relationship, our exchanges take the form of mutual enrichment based on the cross-fertilization of knowledge, making it possible to position support as a relevant research protocol.

We were able to attend or participate in a number of meetings and workshops and organized semi-directed interviews with key-actors to collect information. We also obtained several reports and found on-line information on the ecosystem. The data come mainly from interviews, meetings and workshops with Fil’Innov managers and staff (field support and researchers) involved in this service between 2016 and 2018.

2.3. Conceptual framework for Data analysis

Our methodology followed five steps. First, we build a literature review on Industry 4.0 to capture its key technologies, its main features and its principles applications. Second, as BMs have the potential to disrupt entire industries (Bidmon & Knab, 2018) and as intermediaries have the potential to germinate change towards socio-technical transitions (Kivimaa, 2014), we reviewed a

literature on BM innovation, sustainable and circular BMs as well as innovation and transition intermediaries. Third, we crossed the two literatures to identify the levers and drawbacks in order to make Industry 4.0 more sustainable with a Triple bottom line approach. Fourth, we carried out a unique case study with Fil'innov. Its aim is to connect the university with its ecosystem in order to follow-up collaborative innovation projects with two research priorities: Industry of the future and Healthcare of the future. Fifth, by comparing the literature and the current organization of Fil'innov, we wish to develop theoretical and practical tools to find the most relevant and innovative support to renew the perspectives in the regional ecosystem by linking Industry 4.0 and sustainability.

3. A theoretical framework to address the transition towards sustainable ecosystem

This section reminds the position and the missions of public intermediary organizations (PIO) (3.1.) and reviews the Industry 4.0 literature (3.2.). We are willing to identify its key technologies (3.2.1), main features (3.2.2) and applications (3.2.3). These reports underlie the emergence of new BMs, allowing the creation of more collaborative environments. Through a literature review on BM innovation (BMI), we finally identify models that could support PIOs in addressing the process of transition (3.3.). This opens, for public intermediary organizations such as Fil'Innov, avenues in which BM innovation could support sustainability and circular economy within industry 4.0.

3.1. Position and the missions of public intermediary organizations

3.1.1. The intermediary organization in innovation ecosystems: the structuralist approach

With regard to the potential for creating economic value from academic research, a public intermediary organization supporting innovation is developed within the university in order to bridge the different logics of science and industry whereas maintaining the different nature of the systems, and to keep the diversity which stimulates innovation (Kaufmann & Tödtling, 2001).

Therefore, levels of action and value system (from value creation to value delivery) may vary according to the types of activities (IT, Health, Biology....) and the specific regulations and requirements of the business activities. They depend on local, regional, national and transnational perimeters. It is sometimes difficult to distinguish the reasons why the action was initiated as well as the coordination and interactions, within and between networks, clusters, platforms, science parks, agencies, and national or European calls for projects (Schieb-Bienfait & Boldrini, 2016).

In this context, the intermediary organization plays an increasingly important role, but it must always be considered within its innovation ecosystem, the relevant framework for analysis (Adner, 2017). In our research, we chose the structuralist approach to ecosystems *“defined by the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize”* (Adner, 2017, p. 42). Adner (2017) suggests that this approach is complementary to the ecosystems-as-affiliation approach, usually focusing on measures such as number of partners, network density, and actors' centrality in networks. The ecosystems-as-structure approach considers interdependent value creation, starting with a value proposition and seeking to identify the set of actors that need to interact. Four basic elements characterize the configuration of the

ecosystem in this approach: activities, actors, positions and links. This ecosystem-as-structure perspective can highlight partner alignment as a critical strategic challenge in order to address the processual transition to the sustainable innovation ecosystem.

In our data analysis approach, we therefore aim to provide some clues to better address the ecosystem level of innovation towards sustainability: if some actors start to consider new behaviors and models, then the ecosystem may evolve through the alignment process.

3.1.2. Missions of Innovation and transition intermediary organizations

If increasing attention has been paid to intermediaries, due to their key mission in connecting multiple actors in innovation and transition processes (Howells, 2006; Kivimaa, 2014), the issues related to sustainability and circular economy are still unexplored. In distributed innovation systems, intermediaries are involved in more complex relationships, such as “may-to-one-to-one”, “one-to-one-to-many”, “many-to-one-to-many” (Howells, 2006, p. 724). In this perspective, we consider that intermediary organizations could develop their relational innovation capabilities according to sustainable behaviors and devices which still remain to be identified and conceived in narrow collaboration with their innovation ecosystem. Alexander and Martin (2013) have considered a wide array of services offer for transfer offices, ranging from transactions¹-focused activities to relations-focused ones. The four main core competences they have identified could be seen as the four key fields to address: (i) set up and managing research project, (ii) knowledge sharing and support services to enterprises, (iii) boundary spanning through human resources, and (iv) patent and entrepreneurship (Alexander and Martin, 2013).

As research has highlighted that intermediary organizations can operate in many levels to support innovation and advance transitions, we can assume that Intermediary functions could introduce new ways to support experimentation on a sustainable manner, and to further aggregate knowledge, pooling resources, network building and stronger institutional support and capacity building in an acceleration but nevertheless circular perspective (Kivimaa, Hyysalo, et al., 2019b). Intermediary actors could be considered as key catalysts that speed up change towards more sustainable ecosystems. Kivimaa et al. (2019a) provide a typology of five intermediary types and it appears that systemic and niche intermediaries are the most crucial forms of intermediary actors in transitions, but they need to be complemented by other kinds of intermediaries, such as regime-based transition intermediaries, process intermediaries and user intermediaries.

3.2. Industry 4.0: a literature metareview on technologies, features and applications

This section briefly presents the key technologies of Industry 4.0 (3.3.1), its main features (3.3.2) and applications (3.3.3).

¹ Relational practices are based on interpersonal links and trust, when transactional ones are based on codified scientific and technological knowledge (Garcia-Perez-de-Lema et al., 2016). Recent studies have emphasized that relations-focused practices support transactions-focused ones (Garcia-Perez-de-Lema et al., 2016; Weckowska, 2015).

3.2.1. Key Technologies

The highly flexible production in reduced times, the improved product quality and the organizational performance of Industry 4.0 are made possible with the digitization of manufacturing which brings together the digital and physical worlds through Cyber-Physical Systems (Kagermann, 2015; Pereira & Romero, 2016; Kamble, 2018). The emerging Industry 4.0 concept is an umbrella term that embraces a set of future industrial developments regarding Cyber-Physical Systems (CPS), Internet of Things (IoT), Internet of Services (IoS), Robotics, Big Data, Cloud computing allowing efficiency and productivity improvements (Pereira & Romero, 2017). The continuous interaction and exchange of information are not only between machines, but also between humans, and between humans and machines. The interconnection is made possible with a combination of physical devices, software, sensor, processor, and communication technologies (Kamble et al., 2018). Cyber-Physical Systems (CPS) can be defined as industrial automation systems with innovative computing, communication, and control technologies. These tightly integrated technologies establish global networks for business (Lu, 2017; Pereira & Romero, 2017; Vaidya et al., 2018).

The Internet of Things (IoT) can be defined as the connection between Internet, physical objects in shop floors (CNC machines tools, robots, sensors, actuators...), and people (Pereira et al., 2018). IoT technology offers efficient and reliable solutions for collecting, storing, analyzing, and processing a wide variety of data and for controlling manufacturing process (Kagermann, 2015). As such, it enables real-time production, planning and control, real time data monitoring as well as tracking the status and positions of product (Kamble et al., 2018; Vaidya et al., 2018). Advanced predictive analytics allow fast transmission of data/information, remote manufacturing activities, and a facilitated collaboration among stakeholders to improve productivity (Lu, 2017; Kamble et al., 2018). As a worldwide network of objects (Vaidya et al., 2018), the IoT is intricately linked to information about their provenance, use, and destination as these objects communicate via standard protocols and are allotted unique identifiers (Kamble et al., 2018). IoT offers new opportunities for high value services to industry leading to the notion of Internet of Services (IoS). The relationships among customers and producers being changed, the customers become more involved in decisions about quality and the customization of products (Lu, 2017). The next innovation is Internet of Everything (IoE) where subjects and objects alike can communicate in real time (Kagermann, 2017).

Cloud technologies and big data analytics (BDA) are interlinked with the IoT because Industry 4.0 is knowledge intensive and requires the management of massive data and information exchange at high speeds with any other device or person anywhere in the world (Kagermann, 2015; Lu, 2017; Vaidya et al., 2018). Cloud systems, that can be accessed anywhere in the world, increase data sharing across company boundaries and offer economies of operation, speed of service, massive scale of operation. Then, big data analytics and technologies improve manufacturing flexibility, quality, and efficiency (Kamble et al., 2018). Autonomous robots, industrial wireless networks, sensors, radio frequency identification (RFID), and 3D printing used to produce small batches of customized products, are also commonly cited technologies for Industry 4.0 (Liao et al., 2017; Kamble et al., 2018; Vaidya et al., 2018).

3.2.2. Main features

Built upon the key technologies, the main often cited features for Industry 4.0 are digitization, integration, interoperability, standardization, modularity, decentralization, virtualization, flexibility, customization of production, and Service-Oriented Architecture (SOA) (Lu, 2017; Kamble et al., 2018; Vaidya et al., 2018). Digitization is the continuing convergence, enabled by information and communication technology (ICT), of the real and the virtual worlds and the increased networking of people and things (Kagermann, 2015). Integration embraces the CPS technologies which eliminate the boundaries between the digital and physical world, integrate human and machine agents, materials, products, production systems and processes (Pereira & Romero, 2017; Liao et al., 2017). Production cells are then transformed into the fully integrated, automated, and optimized production flow of Industry 4.0 (Vaidya et al., 2018). Integration may be horizontal, vertical, or end-to-end digital. Horizontal Integration refers to the integration of the various IT systems used in the different stages of the manufacturing and business processes within a company. Vertical Integration is the integration of the various IT systems at the different hierarchical levels. Vertical and horizontal integration enables end-to-end digital integration across the entire value chain (Kagermann, Wahlster, and Helbig 2013; Liao et al., 2017; Kamble et al., 2018). Integration intends (i) to create smarter processes without human intervention but with autonomous control on their operations to cater the rapidly changing market requirements, (ii) to enable mass customization in manufacturing, and (iii) to reduce operational costs along the value chain (Pereira et al., 2017; Kamble et al., 2018). Interoperability is the ability of two or more systems to perform the same function by exchanging data and sharing information and knowledge, even on switching the machines and equipment throughout diversified, heterogeneous, and autonomous procedures (Lu, 2017; Kamble et al., 2018). Standardization results from the need to ensure an accurate and efficient interoperability and to secure reliable communications (Lu, 2017; Liao et al., 2017; Kamble et al., 2018; Vaidya et al., 2018). Modularity refers to the capacity to reconfigure production systems in a more adapted way. Modularity allows adjustments in production capacity in case of seasonal fluctuations or in changes production needs. (Kamble et al., 2018). Decentralization is the ability of companies, operations staff, and even machines to make autonomous decisions about production planning and control (Kamble et al., 2018). Virtualization consists in creating a virtual duplicate of the physical world. Thanks to visualization technologies (augmented or virtual reality), virtualization helps to avoid failures of the system or to ensure safety provisions (Liao et al., 2017; Kamble et al., 2018). The interconnection of all the entities, enabled by IT, improves manufacturing flexibility, quality, and efficiency. It allows organizations to respond easier and quicker to market changes, to co-create value within stakeholders' partnerships or to customize the production (Pereira & Romero, 2017; Kamble et al., 2018). More broadly, a service orientation facilitates innovative applications.

3.2.3. Principal applications

There is a consensus about the main applications that address Industry 4.0: (i) smart Factory, (ii) smart products, (iii) simulation and prototypes, (iv) customer as an active participant, and (v) BMs (Pereira & Romero, 2017; Lu, 2017; Kamble, 2018). The applications of Industry 4.0, based on CPS, IoT, BDA, cloud computing, sensors, etc. are often qualified as "smart" (Kagermann, 2015; Lu, 2017) because they are composed of independent and autonomous devices that are able to communicate

and cooperate in real-time with other smart devices (Pereira & Romero, 2017). Smart Factory results in integration, digitization and use of flexible structures and smart solutions (Pereira & Romero, 2017). The integrative real-time intercommunication between every resource (sensors, actuators, conveyors, machines, robots, etc.) increases the manufacturing efficiency, achieves high levels of self-optimization and automation and allows the meeting of highly complex market requirements (Pereira & Romero, 2017; Lu, 2017). Additive manufacturing techniques, such as 3-D printing, will help manufacture small batches of customized products (Kamble et al., 2018). Smart products refer to objects, devices, and machines equipped with sensors, controlled by software, connected to the internet, and uniquely identifiable. (Kamble et al., 2018). They make the increasing complexity of manufacturing processes manageable and allow human beings to communicate with products (Lu, 2017; Kamble et al., 2018). Smart products have a high degree of autonomy, being able to perceive and interact autonomously with their physical environment over their lifecycle (Pereira & Romero, 2017). Virtualization offers wide possibilities in simulation and prototyping. Operators can virtually test and optimize the machine settings for the next product in line before the physical changeover. The movements and machining operations may be observed through simulation in virtual commissioning in order to prevent collisions, to reduce the production failures during the start-up phase, or to track manufacturing cost or energy consumption (Kamble et al., 2018; Vaidya et al., 2018). Locating and selecting spare parts in a warehouse as well as sending maintenance repair instructions over mobile devices are made easier with augmented reality-based systems (Kamble et al., 2018; Vaidya et al., 2018). With the Internet of Services (IoS), both internal and cross organizational services are offered to the participants of the value chain (Lu, 2017). This will challenge the role of the customer. He will not only become more aware and demanding regarding lead time delivery services and product availability and reliability, but he will also be transformed in an active participant in the value creation process or even in a co-producer (Kamble et al., 2018). Finally, new BMs are emerging, with Industry 4.0, allowing the creation of collaborative environments (Pereira & Romero, 2017).

3.3. From Business modeling to sustainable Ecosystem Modeling: a multi-level approach around new issues

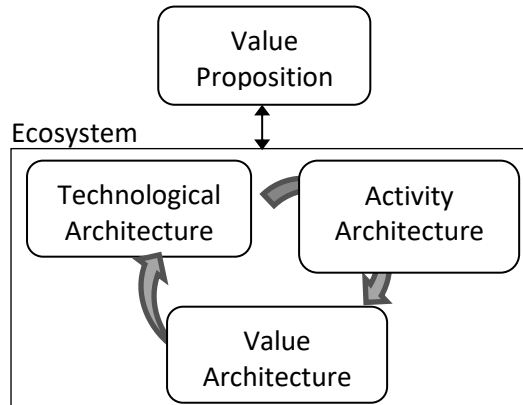
A BM can be defined as a template of how an organization creates, delivers and captures value (Osterwalder & Pigneur, 2010; Teece, 2010). BMs are important for achieving systemic change as they have the potential to disrupt entire industries because they connect multiple actors, mediate between the production and the consumption side of business and support the introduction of novel technologies into the market (Bidmon & Knab, 2018).

In the transition perspective towards circular economy, we are, with the conventional BM canvas approach (Osterwalder & Pigneur, 2010), quickly confronted with limitations. This model, for example, does not allow for the effective consideration of relations with the ecosystem, nor with the plural dimensions of value creation (Schieb-Bienfait, Saives, Émin, Desmarteau, & Holford, 2013). As for value, we consider that the Triple Bottom Line approach (Elkington, 1997), embracing the economic, social and environmental dimensions requires another framework of analysis.

To better understand ecosystem creation and evolution, Autio and Thomas(2014) consider three related architectures: (i) the Technological Architecture defining the main shared technological

resources and platforms and their access, (ii) the Activity Architecture specifying the composition, roles, specialization drivers and coordination mechanisms (iii) the Value Architecture, describing the resulting value dynamic, including control mechanisms for appropriation and sharing and value externalities to secure viability and sustainability and (iv) articulating the Ecosystem Value Proposition to these architectures offers an interesting frame that we called the “Ecosystem Model” (See Figure 1).

Figure 1: Ecosystem Model Framework



In order to address the tensions identified in the first section of this paper, we will concentrate on BM innovation through Industry 4.0 (Ibarra et al., 2018; Geissdoerfer & Weerdmeester, 2019) on BMs related to sustainability (Stock & Seliger, 2016; de Man & Stranhagen, 2017; Kamble et al., 2018; Braccini & Margherita, 2019) and circular economy (Tseng et al., 2018; de Sousa Jabbour et al., 2018a, 2018b).

The aims of sustainable BMs are to: (i) create significant positive and/or significantly reduced negative impacts for the environment and/or society, (ii) incorporate a triple bottom line approach in their value proposition and their logic of value creation, delivery and capture, (iii) use both a system and a firm-level perspective, (iv) consider, with a pro-active management, a wide range of stakeholder interests, including environment and society, and (v) adopt a long term perspective (Stubbs & Cocklin, 2008; Bocken et al., 2014, 2018; Geissdoerfer et al., 2018).

To establish the concept of circular economy (CE), four relevant components are necessary: “1) the recirculation of resources and energy, the minimization of resources demand, and the recovery of value from waste, 2) a multi-level approach, 3) its importance as a path to achieve sustainable development, and 4) its close relationship with the way society innovates.” (Prieto-Sandoval et al., 2018, p. 610). BM innovation is considered a cornerstone for CE transition as it supports firms in shifting their business paradigms (Lewandowski, 2016; Antikainen & Valkokari, 2016; Bocken et al., 2018). The transition to a circular economy entails four fundamental building blocks (i) materials and product design (ii) new BMs (iii) global reverse networks (iv) enabling conditions (Planing, 2015).

Linder and Willander (2015, p. 183) define a circular BM “as a business model in which the conceptual logic for value creation is based on utilizing economic value retained in products after use in the production of new offerings. Thus, a circular BM implies a return flow to the producer

from users. The value creation logic is designed to improve resource efficiency through contributing to extending useful life of products and parts (Nußholz, 2017). The best sustainability performance is achieved in a circular BM if all its elements are aligned to support the three functions: value proposition, value creation and delivery, and value capture (Geissdoerfer et al., 2018). Circular BM innovations are by nature networked and require circular supply chain management within complex networks of interdependent actors/stakeholders (Bocken et al., 2014; Antikainen & Valkokari, 2016). Circular supply chains must consider not only the production and distribution activities but also the consumption processes (Lieder & Rashid, 2016). Without a supply-side view the risk is to develop unviable circular BMs due to lacking consumer demand (Kirchherr et al., 2017). According to Urbinati et al. (2017, p. 490), adapting or creating a new BMs with CE principles requires four main modifications: “on the one hand, to implement reverse supply chain activities and a higher degree of cooperation with the actors of the supply chain, and on the other hand, a new value proposition for customers, which requires a new way to perceive the buying process and a higher degree of cooperation between companies and customers themselves.”

As digitalization, after automation, is breaking down the traditional barriers of the industry, there is a need to rethink the existing BMs (Ibarra et al., 2018) and especially to promote sustainable ones (Stock & Seliger, 2016; de Man & Strandhagen, 2017; Kamble et al., 2018) as well as circular economy (Tseng et al., 2018; de Sousa Jabbour, 2018a). Products become smarter, more modular and configurable allowing mass customization in order to meet specific customer requirements. New products and services are embedded in systems that can become responsive and interactive as their status well as their activity can be tracked in real time during their lifecycle optimizing the whole value chain (Pereira & Romero, 2017).

To embrace the digitalization, Ibarra et al. (2018) propose four different ways to innovate on the BMs: (i) optimizing internal and external processes, (ii) improving customer relationship, (iii) to creating new value networks or smart products and services, (iv) through disruptive BMs. To make firms getting closer to the industry 4.0, the same authors suggest three different approaches affecting BMs: service orientation, networked ecosystems and customer orientation (Ibarra et al., 2018). With regard to flexibilization, Geissdoerfer and Weerdmeester (2019) have identified four BM archetypes: (i) Decentralized/Modular, (ii) Mass Customization, (iii) PSS/Servitization, (iv) Reuse, Recycle and Sustainability that can also facilitate the relocation of industry.

Stock and Seliger (2016) think that Industry 4.0 provides immense opportunities for realizing sustainable manufacturing. Its technologies can enable an efficient allocation of resources, with design for environment, cleaner production or green supply chain initiatives (de Sousa Jabbour et al., 2018b). De Man and Strandhagen (2017) also acknowledge a potential for sustainable offerings by designing products for longevity, repair and recycling, using fewer raw materials, and by creating value through exploiting the available data collection. These authors however observe that Industry 4.0 has firstly been introduced to enable high-tech competitive advantage. As such Industry 4.0 can also be an inhibitor to sustainable BMs because sustainability cannot support neoclassical BMs.

Lieder and Rashid (2016) were probably among the first authors to link manufacturing industry and CE but the connection between the CE and Industry 4.0 technologies has not been extensively discussed (de Sousa Jabbour et al., 2018a). Tseng et al. (2018) consider that data-driven analysis can

potentially be used to optimize the sustainable solutions intended to reduce the resource and emission intensities of industrial systems. Among all CE principles, most authors focus on the supply chain management to develop a CE. For de Sousa et al. (2018a, 2018b), digital manufacturing technologies, and especially big data, are able to unlock the circularity of resources within supply chains. More conventionally, the strategies to reduce the need for new raw materials are based on closed-loops, reverse logistics and Rs principles (reduce, reuse, recycle, repair, refurbish...) (de Man & Strandhagen, 2017; Tseng et al., 2018). In the past, the recovery efforts targeted simple consumer products. With industry 4.0 the challenges are greater. As Smart products are complex and manufactured with multiple materials that make difficult identification and separation when the products have reached their end of their life (Tam et al., 2019).

Among the different Industry 4.0 approaches affecting BMs, it has been suggested to make firms getting closer to service orientation, networked ecosystems and customer orientation (Ibarra et al., 2018). To address our issues, several proposals can be pointed out:

- i) The perspective of New Ecosystems and Value Networks. This model proposes a radical innovation of the actual BM which follows the purpose of focusing on the core business (key or distinctive activities of the firm), sharing the uncertainty with other agents or achieving new required skills and resources from associates, due to the introduction of technologies (...) Moving from value chains to ecosystems and, in consequence, increasing stakeholders' knowledge requires a radical change in many of the BM elements (key activities, channels and relationships) with both customer and partnerships (Ibarra et al., 2018).
- ii) The perspective of New BMs, smart products and services. In contrast to the previous case, this type proposes a completely new BM based on new technologies focused on Big Data, Cloud Computing, Intelligent Sensorisation and Embedded Systems, among others, that allows offering innovative and smart goods and services (Ibarra et al., 2018).

As we can report, it will be necessary for the Intermediary Organizations (IOs) to experiment BMs related to sustainable innovation ecosystem in order to deal with this transition processual steps. In our next section, we attempt to anticipate what could be the first steps for Fil'Innov, as a transition intermediary innovation organization.

4. Discussion and conclusion

In the previous sections, we provided answers to our first research question which was to identify the challenges a public intermediary organization must face to become a leading actor in innovation ecosystems 4.0. In this section, we intend to answer our second research question which is to determine the extent to which the BM approach would be relevant to identify transition trajectories to develop sustainable and innovative ecosystems

From the identification of the challenges met by the studied public IO Fil'Innov, we propose to use a BM approach to find out the first steps to promote, an orientation towards a sustainable innovation ecosystem.








The position and missions of Fil'innov, as a transition intermediary in the 4th Industrial (R)evolution context, will be crucial in the coming years. It will require to support and to equip this transition towards a sustainable innovation ecosystem.

Despite its limits for sustainability and circularity, we have chosen to keep the BM canvas (BMC) (Osterwalder & Pigneur, 2010) to introduce the transition, due to its current worldwide recognition. As a common language for modeling, the BMC can help Fil'Innov to assess the resources, skills, activities, value propositions: (i) that already exist and that go in the same way than those of the TBL approach, (ii) those that are potentially present but need to be recombined, and (iii) those that are missing. We propose to introduce some tools for practitioners and policy makers to assess, visualize and discuss with other stakeholders the evolution of their BMs and of the innovation ecosystem towards sustainability, drawing on the 4th Industrial (R)evolution dynamics and changes.

In this perspective Fil'innov should encourage its partners to collaborate and to develop a new sustainable BM with relations-focused activities, creating knowledge, making connections and building trust. The challenge is to address the different tensions and challenges we have identified in order to discuss how to foster the sustainable development of the innovation ecosystem with various other organizations, within the university or within other institutional organizations.

A 3-step Transition Process

STEP 1: BM Canvas – Current analysis of Fil'innov as an innovation intermediary and limits encountered due to the 4th Industrial (R)evolution








<p>Key Partners </p> <p>Researchers, laboratories</p> <p>Companies</p> <p>Local authorities</p> <p>Other intermediary organizations</p>	<p>Key Activities </p> <p>(i) knowledge sharing and support services to firms and labs (ii) boundary spanning through HR</p> <p><u>Dealing with transdisciplinarity</u></p>	<p>Value Proposition </p> <p>“Find the right person for the best information”</p> <p>Industry based expertise</p> <p>Techno-push</p> <p>Pluridisciplinarity of the team</p> <p><u>Digitalization in every sector</u></p> <p><u>Social acceptability to be improved in many sectors</u></p> <p><u>Customer needs:</u></p>	<p>Customer Relationships </p> <p>Highly personalized relationship</p> <p><u>Complexity</u></p>	<p>Customer Segments </p> <p>Researchers, laboratories</p> <p>Companies</p> <p>Local authorities</p> <p>Other intermediary org.</p> <p><i>Increasing potential (SMEs, area)</i></p>
<p>Cost Structure </p> <p>Salaries and infrastructure</p> <p><i>Shared digital tools</i></p>		<p>Revenue Streams </p> <p>Public subsidies</p> <p>Social benefits: Knowledge sharing, contribution to the economic development of the territory</p>		

Black: Current BM

Red: limit or problem to deal with due to the 4th Industrial (R)evolution

Green: advantage or improvement from the 4th Industrial (R)evolution

STEP 2: BM Canvas – Suggested ways of development for Fil’innov as a transition intermediary towards sustainability

<p>Key Partners </p> <p>Partners and experts in circular economy and sustainable transitions</p> <p>Research projects on sustainability, TBL approaches and circular economy</p>	<p>Key Activities </p> <p><u>Dealing with transdisciplinarity</u></p> <ul style="list-style-type: none"> -Developing new approaches - Crossing expertise - Developing support towards sustainability - managing complex cross industry projects 	<p>Value Proposition </p> <p><u>Digitalization</u></p> <p><u>Social acceptability:</u> Information and sensitization about sustainability</p> <p>Activities with low environmental impacts</p> <p><u>Customer needs: market-pull</u></p> <p>Developing larger interfaces with researchers and companies</p>	<p>Customer Relationships </p> <p><u>Complexity</u></p> <p>Increasing integration and interfaces</p>	<p>Customer Segments </p> <p>No change: sustainability should address each kind of target</p>
<p>Cost Structure </p>				<p>Revenue Streams </p>
<p><u>Social & environmental costs</u></p>		<p><u>Social & environmental benefits</u></p>		

Red: limit or problem to deal with due to the 4th Industrial (R)evolution
 Green: suggested improvement

STEP 3: Ecosystemic perspective

Working on the ecosystem perspective allows us to highlight some of the key features that would allow the ecosystem to move towards more sustainable perspectives.

Innovation Support Ecosystem 4.0 – Potential changes towards sustainability

Value architecture		Value proposition		
Value Network		Activity Architecture	Mission / Offer	Beneficiaries
Key-activities: <i>Open innovation</i> Transactional: IP management Relational: <i>Not only shared premises but increased mentoring, networking, knowledge spillover</i>	Actors of the ecosystem: Intermediary organizations Researchers, laboratories Companies Local authorities	Positions and roles: <i>More integrated intermediary actors</i>	<i>“Find the right persons, the right places, the best technologies and adequate support to develop your project in a sustainable way”</i> Support on: -Digitalization transition -Social acceptability -Sustainability Open innovation practices Customer needs: market-pull	Researchers, laboratories Companies Local authorities
Shared resources: Shared infrastructures (VR, AR, etc) Increasing technology level <u>Quick obsolescence?</u> <i>Sharing costs and risks</i>	<i>Users: Working on social acceptance of technologies and innovations</i>	Coordination mechanisms: Agreements <i>Coopetition</i> <u>Power, legitimacy?</u>		
Value co-creation				
Regulation Mechanisms: <i>Open innovation</i> Formal agreements <u>Data access?</u> <u>Knowledge access?</u> <u>Power, legitimacy?</u>	Value dimensions: Economic Technical Social Environmental	Value creation: <i>Sustainable</i> E: New business T: Knowledge S: Inclusion E: Eco-friendly	Capture/sharing: E: <i>Integration</i> <i>Mutualization</i> T: <i>Knowledge Access?</i>	Funded by: Public subsidies Private investment

Black: Current Model

Red: limit or problem to deal with due to the 4th Industrial (R)evolution

Green: *Suggestion to improve the current model towards a sustainable innovation ecosystem 4.0*

Our main results show that as an intermediary actor Fil’innov should probably develop its BM towards the “New Ecosystems and Value Networks” type proposed by Ibarra et al. (2018) as it already shows some of its characteristics. The purpose of this model is to focus on the core business (key or distinctive activities of the organization), sharing the uncertainty with other actors or achieving new required skills and resources from partners, due to the introduction of technologies. It also implies moving from value chains to ecosystems and, in consequence, increasing stakeholders’ knowledge. Finally, it requires a radical change in many of the BM elements (key

activities, channels and relationships) with both customer and partners. However, we are only at the beginning, our research to date raises more questions than it provides answers, but this makes it possible to identify avenues of work for future studies.

References

- Adner, R. (2017). Ecosystem as Structure: An Actionable Construct for Strategy. *Journal of Management*, 43(1), 39–58.
- Alexander, A. T., Martin, D. P. (2013). Intermediaries for open innovation: A competence-based comparison of knowledge transfer offices practices. *Technological Forecasting and Social Change*, 80(1), 38–49.
- Antikainen, M., Valkokari, K. (2016). A framework for sustainable circular business model innovation. *Technology Innovation Management Review*, 6(7), 1-12.
- Autio, E., Thomas, L. D. W. (2014). Innovation Ecosystems, in Dodgson, M, Philips, N., Gann, D. M. (Eds). *The Oxford Handbook of Innovation Management*, Oxford University Press, 204-288.
- Ayres, R. U. (1991). *Computer integrated manufacturing: Revolution in progress* (Vol. 1). Dordrecht, Springer Science & Business Media.
- Bidmon, C. M., Knab, S. F. (2017). The three roles of business models in societal transitions: New linkages between business model and transition research, *Journal of Cleaner Production*, 178, 903-916.
- Blomsma, F., Brennan, G. (2017). The emergence of circular economy: A new framing around prolonging resource productivity. *Journal of Industrial Ecology*, 21(3), 603-614.
- Bocken, N. M., Short, S. W., Rana, P., Evans, S. (2014). A literature and practice review to develop sustainable business model archetypes. *Journal of cleaner production*, 65, 42-56.
- Bocken, N. M. P., Schuit, C. S. C., Kraaijenhagen, C. (2018). Experimenting with a circular business model: Lessons from eight cases. *Environmental Innovation and Societal Transitions*, 28, 79-95.
- Braccini, A., Margherita, E. (2019). Exploring Organizational Sustainability of Industry 4.0 under the Triple Bottom Line: The Case of a Manufacturing Company. *Sustainability*, 11(1), 36.
- Bréchet, J.-P., Émin, S., Schieb-Bienfait, N. (2014). La recherche-accompagnement : une pratique légitime. *Finance Contrôle Stratégie*, 17(2), 25-46.
- Champenois, C., Etzkowitz, H. (2018). From boundary line to boundary space: The creation of hybrid organizations as a Triple Helix micro-foundation. *Technovation*, 76, 28-39.
- De Man, J. C., Strandhagen, J. O. (2017). An Industry 4.0 research agenda for sustainable business models. *Procedia Cirp*, 63, 721-726.
- De Sousa Jabbour, A. B. L., Jabbour, C. J. C., Godinho Filho, M., Roubaud, D. (2018a). Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. *Annals of Operations Research*, 270(1-2), 273-286.
- De Sousa Jabbour, A. B. L., Jabbour, C. J. C., Foropon, C., Godinho Filho, M. (2018b). When titans meet—Can industry 4.0 revolutionise the environmentally-sustainable manufacturing wave? The role of critical success factors. *Technological Forecasting and Social Change*, 132, 18-25.
- Demil, B., Lecocq, X. (2010). Business model evolution: in search of dynamic consistency. *Long Range Planning*, 43(2), 227–246.

- Ekman, P., Raggio, R. D., Thompson, S. M. (2016). Service network value co-creation: Defining the roles of the generic actor. *Industrial Marketing Management*, 56, 51–62.
- Elkington, J. (1997). *Cannibals with forks: The triple bottom line of 21st century*, Oxford, UK: Capstone.
- Ellul, J. (1971). *Autopsy of revolution*, New York, Knopf.
- Etzkowitz, H., Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and “Mode 2” to a Triple Helix of university–industry–government relations. *Research Policy*, 29(2), 109–123.
- Garcia-Perez-de-Lema, D., Madrid-Guijarro, A., Martin, D. P. (2016). Influence of university–firm governance on SMEs innovation and performance levels. *Technological Forecasting and Social Change*, 123, 250–261.
- Geissdoerfer, M., Morioka, S., de Carvalho, M., Evans, S. (2018). Business models and supply chains for the circular economy, *Journal of Cleaner Production*, 190, 712–721.
- Geissdoerfer, M., Weerdmeester, R. (2019). Managing business model innovation for relocalization in the process and manufacturing industry. *Journal of Business Chemistry*, 1, 11–25.
- Gertler, M. S., Wolfe, D. A. (2004). Local social knowledge management: Community actors, institutions and multilevel governance in regional foresight exercises. *Futures*, 36(1), 45–65.
- Ghisellini, P., Cialani, C., Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, 114, 11–32.
- Gioia, D. A., Corley, K. G., Hamilton, A. L. (2013). Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology. *Organizational Research Methods*, 16(1), 15–31.
- Grimaldi, R., Kenney, M., Siegel, D. S., Wright, M. (2011). 30 years after Bayh–Dole: Reassessing academic entrepreneurship. *Research Policy*, 40(8), 1045–1057.
- Howells, J. (2006). Intermediation and the role of intermediaries in innovation. *Research Policy*, 35(5), 715–728.
- Ibarra, D., Ganzarain, J., Igartua, J. I. (2018). Business model innovation through Industry 4.0: A review. *Procedia Manufacturing*, 22, 4–10.
- Kagermann, H., Wolfgang W., Helbig, J. (2013). Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0. Final report of the Industrie 4.0 Working Group, Berlin: Industrie 4.0 Working Group of Acatech.
- Kagermann, H. (2015). Change through digitization—Value creation in the age of Industry 4.0. In *Management of permanent change*, Springer Gabler, Wiesbaden, 23–45.
- Kamble, S. S., Gunasekaran, A., Gawankar, S. A. (2018). Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives. *Process Safety and Environmental Protection*, 117, 408–425.
- Kaufmann, A., Tödtling, F. (2001). Science–industry interaction in the process of innovation: the importance of boundary-crossing between systems. *Research Policy*, 30(5), 791–804.
- Kirchherr, J., Reike, D., Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, 127, 221–232.
- Kivimaa, P. (2014). Government-affiliated intermediary organisations as actors in system-level transitions. *Research Policy*, 43(8), 1370–1380.
- Kivimaa, P., Boon, W., Hyysalo, S., Klerkx, L. (2019a). Towards a typology of intermediaries in sustainability transitions: A systematic review and a research agenda. *Research Policy*, 48(4), 1062–1075.

- Kivimaa, P., Hyysalo, S., Boon, W., Klerkx, L., Martiskainen, M., & Schot, J. (2019b). Passing the baton: How intermediaries advance sustainability transitions in different phases. *Environmental Innovation and Societal Transitions*, *in press*.
- Landry, R., Amara, N., Cloutier, J.-S., Halilem, N. (2013). Technology transfer organizations: Services and business models. *Technovation*, 33(12), 431–449.
- Lewandowski, M. (2016). Designing the business models for circular economy. Towards the conceptual framework. *Sustainability*, 8(1), 43.
- Liao, Y., Deschamps, F., Loures, E. D. F. R., Ramos, L. F. P. (2017). Past, present and future of Industry 4.0-a systematic literature review and research agenda proposal. *International journal of production research*, 55(12), 3609-3629.
- Lieder, M., Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, 115, 36-51.
- Linder, M., Williander, M. (2015). Circular business model innovation: inherent uncertainties. *Business Strategy and the Environment*, 26(2), 182-196.
- Lu, Y. (2017). Industry 4.0: A survey on technologies, applications and open research issues. *Journal of Industrial Information Integration*, 6, 1-10.
- Merli, R., Preziosi, M., Acampora, A. (2018). How do scholars approach the circular economy? A systematic literature review. *Journal of Cleaner Production*, 178, 703-722.
- Nußholz, J. L. (2017). Circular Business Models: Defining a Concept and Framing an Emerging Research Field. *Sustainability*, 9(10), 1810.
- Pereira, A. C., Romero, F. (2017). A review of the meanings and the implications of the Industry 4.0 concept. *Procedia Manufacturing*, 13, 1206-1214.
- Planing, P. (2015). Business model innovation in a circular economy reasons for non-acceptance of circular business models. *Open journal of business model innovation*, 1, 11.
- Prieto-Sandoval, V., Jaca, C., Ormazabal, M. (2018). Towards a consensus on the circular economy. *Journal of Cleaner Production*, 179, 605-615.
- Osterwalder, A., Pigneur, Y. (2010). *Business model generation: a handbook for visionaries, game changers, and challengers*. John Wiley & Sons.
- Özdemir, V., Hekim, N. (2018). Birth of industry 5.0: Making sense of big data with artificial intelligence, “the internet of things” and next-generation technology policy. *Omicron: a journal of integrative biology*, 22(1), 65-76.
- Parker, A., Halgin, D. S., Borgatti, S. P. (2016). Dynamics of Social Capital: Effects of Performance Feedback on Network Change. *Organization Studies*, 37(3), 375–397.
- Rifkin, J. (2011). *The third industrial revolution: how lateral power is transforming energy, the economy, and the world*. New York, Palgrave Macmillan.
- Rotmans, J., Kemp, R., Van Asselt, M. (2001). More evolution than revolution: transition management in public policy. *foresight*, 3(1), 15-31.
- Sachsenmeier, P. (2016). Industry 5.0 — The relevance and implications of bionics and synthetic biology. *Engineering*, 2(2), 225-229.
- Schieb-Bienfait, N., Saives, A.-L., Émin, S., Desmarteau, R., Holford, D. (2013). Business Model as Mediator of Value Creation: What Value are we talking about? *29th EGOS colloquium*, Montreal, July 4–6.

- Schieb-Bienfait, N., Boldrini, J.-C. (2016). La valorisation de la recherche publique à l'échelon des Régions françaises : quels enjeux, quels leviers d'activation ? *Revue Management et Avenir*, 83, 165–187.
- Spigel, B. (2017). The Relational Organization of Entrepreneurial Ecosystems. *Entrepreneurship Theory and Practice*, 41(1), 49–72.
- Stock, T., Seliger, G. (2016). Opportunities of sustainable manufacturing in industry 4.0. *Procedia Cirp*, 40, 536-541.
- Stubbs, W., Cocklin, C. (2008). Conceptualizing a “sustainability business model”. *Organization & Environment*, 21(2), 103-127.
- Su, B., Heshmati, A., Geng, Y., Yu, X. (2013). A review of the circular economy in China: moving from rhetoric to implementation. *Journal of Cleaner Production*, 42, 215-227.
- Tam, E., Soulliere, K., Sawyer-Beaulieu, S. (2019). Managing complex products to support the circular economy. *Resources, Conservation and Recycling*, 145, 124-125.
- Teece, D. J. (2010). Business Models, Business Strategy and Innovation. *Long Range Planning*, 43(2–3), 172–194.
- Tseng, M. L., Tan, R. R., Chiu, A. S., Chien, C. F., Kuo, T. C. (2018). Circular economy meets industry 4.0: Can big data drive industrial symbiosis? *Resources, Conservation and Recycling*, 131, 146-147.
- Urbinati, A., Chiaroni, D., Chiesa, V. (2017). Towards a new taxonomy of circular economy business models. *Journal of Cleaner Production*, 168, 487-498.
- Vaidya, S., Ambad, P., Bhosle, S. (2018). Industry 4.0 – a glimpse. *Procedia Manufacturing*, 20(1), 233-238.
- Weckowska, D. M. (2015). Learning in university technology transfer offices: transactions-focused and relations-focused approaches to commercialization of academic research. *Technovation*, 41–42, 62–74.