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Research paper

Restructuring existing value networks to diffuse sustainable innovations in food packaging

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ABSTRACT

Sustainable innovations in food packaging are important in terms of preventing food waste and reducing environmental impact, but existing industry regimes and networks may hinder their diffusion into established markets. However, research on reorientation of existing industries, and value networks in that situation, has been limited. This study examines the changes to existing industry value networks that can facilitate the diffusion of sustainable innovation in food packaging. Empirically, the transformation and distribution of agro-food waste into a new bioplastic packaging through the existing food packaging value network is investigated. As a result, the changes to the existing value network and their connections, facilitating the diffusion of the sustainable innovation, are identified at three levels – firm, network, and macro. The findings show the importance of opportunity recognition, but also the role of new actors, resources, activities, and relationships in the restructuring of the existing value network and actions creating supportive regulative framework and increasing market demand for such renewal. This creates understanding of how the adoption of sustainable innovations, such as new packaging materials, which might seem simple, is complicated by the broad changes required from the existing value network.

1. Introduction

Food waste has significant environmental, social, and economic impacts (Papargyropoulou, Lozano, Steinberger, Wright, & bin Ujang, Z., 2014). It is estimated that one-third of food produced globally is either lost or goes to waste (FAO, 2019), before and after it reaches the consumer. Food waste has thus become a public concern (FAO, 2019) that requires urgent preventative actions from the whole food supply chain (Papargyropoulou et al., 2014), as well as from the regulatory agencies to support sustainable production and consumption (e.g., Australian Government, 2017; European Commission, 2015). In the food industry, a prominent way to prevent food waste is packaging that can protect food products (Lockhart, 1997) from external damages and extend their shelf life (Klewitz & Hansen, 2014). Innovations in package materials and manufacturing processes to better preserve the quality and freshness of food products during their distribution and storage are thus important (Parfitt, Barthel, & Macnaughton, 2010). Specifically, the demand for more sustainable package innovations has increased due to the environmental problems related to packaging.

Bioplastics represent a potential innovation that can advance sustainable development in food packaging. Such innovations have been examined in the literature as sustainable innovations, which include new or improved processes, products, services, organizational and marketing methods that significantly reduce negative or improve positive environmental, social and/or economic impacts (Aka, 2019; Boons & Lüdeke-Freund, 2013; Elkington, 1997). Compared to other innovations, combining ecological and social concerns alongside of economic aspects, however, tends to generate challenges for sustainable innovations in terms of innovation management (Adams, Jeanrenaud, Bessant, Denyer, & Overy, 2016, Silvestre & Tîrca, 2019). For example, sustainable innovations require more intensive internal and external collaboration with different stakeholders, and the related technologies are characterized by a higher degree of complexity and novelty (Messeni Petruzzelli, Maria Dangelico, Rotolo, & Albino, 2011). Therefore, for sustainable innovations to reach wide-scale use, typically both regulative actions as well as entrepreneurial opportunities recognized by the private actors are needed (Lupova-Henry & Dotti, 2019).

In many industries, transitions towards sustainable solutions require

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dismantling existing industry regimes that support the use of old technologies and prevent the change to more sustainable solutions (Gliedt, Hoicka, & Jackson, 2018; Kivimaa & Kern, 2016). Such regimes are socio-technical systems composed of technologies, market practices, cultural meanings, infrastructures, policies, and industry structures that set the framework for behaviors of actors within the industry (Köhler et al., 2019). Established industry regimes thus influence the value networks and may hinder the actors in these networks from adopting new innovations. The change towards sustainable innovations can be considered to be initiated at the firm level, from where the change dissolves into the value network, if more powerful actors become involved (Gliedt et al., 2018; Smith, Voss, & Grin, 2010). However, more research is needed from changes in value networks, enabling the diffusion of sustainable innovations (Adams et al., 2016; Baya & Gruman, 2011; Xavier, Naveiro, Aoussat, & Reyes, 2017). Specifically, when examining the commercialization of sustainable innovations, reorientation of existing industries towards sustainability has received much less attention than the emergence of new industries (Köhler et al., 2019).

A wider perspective, including value networks and systems-level examination, is a prerequisite to understanding the changes to the existing value networks created by sustainable innovations (Adams et al., 2016; Baya & Gruman, 2011; Smith et al., 2010). Therefore, we apply a network approach to examine the changes to existing value networks that can facilitate the diffusion of sustainable innovations. Specifically, we focus on the diffusion of a specific type of bioplastic in food packaging that, by being derived from agro-food waste and by involving food preserving features, represents a sustainable innovation that can be a part of the solution in the fight against food waste. The research question addressed is: *what kinds of changes to the existing industry value networks can facilitate the diffusion of a sustainable innovation in food packaging?*

The research on sustainability transitions (e.g., Geels, 2004; Köhler et al., 2019; Smith et al., 2010) act as a broader theoretical frame, where we employ industrial network and strategic net approaches (e.g., Möller & Rajala, 2007; Möller & Svahn, 2009) to unveil the changes and capture the way of how sustainable innovations spread within the industry value networks. Empirically, we examine the changes that emerge in the existing food packaging plastic value network when a new bio-based, biodegradable plastic packaging solution is introduced as a sustainable innovation that can reduce the environmental impact and enhance the shelf life of food products, thus preventing food waste. As a result, this study presents a framework describing the changes that facilitate sustainable innovation diffusion in the existing food packaging plastic value network. The study thus contributes to the understanding of sustainable innovation diffusion by taking a network approach to identify the changes and their dynamics in the restructuring of existing value networks when commercializing such innovations. In addition, by examining a specific sustainable innovation and the related value network that aims both to prevent food waste by a novel food packaging solution and to recycle agro-food waste into such materials, the findings contribute to the food waste management discussion by demonstrating the complexity of food waste prevention actions.

2. Network view on sustainable innovation

Sustainable innovations, or green innovations that is often used as a synonym for them, influence and are influenced by environmental, social, and economic aspects (Elkington, 1997); for example, such innovations can be environmentally and economically reasonable, but they may have negative social impacts that are difficult to identify. Hence, sustainable innovations are characterized by high levels of complexity as well as novelty compared to other types of innovations (Ardito, Messeni Petruzzelli, & Ghisetti, 2019; Messeni Petruzzelli et al., 2011), which makes their development and commercialization challenging. As Ardito, Messeni Petruzzelli, Pascucci, and Peruffo (2019) point out, although sustainable innovation activities may lead to positive externalities in the form of knowledge creation and environmental benefits, neither are well captured by market prices, thus making governmental intervention and regulatory push essential to compensate for this misalignment.

As with innovations, and with sustainable innovations in particular, it is difficult for a single firm to create a new technology or business. Organizations can try to solve this challenge by searching across varying knowledge domains (Ardito, Messeni Petruzzelli, & Albino, 2016) and by creating webs of knowledge and technological bonds between organizations with complementary skills and resources (Möller & Rajala, 2007; Möller & Svahn, 2009). Indeed, sustainable innovations are often created in complex cross-sector networks, and their development requires collaboration between different stakeholders, such as regulators and other companies (Messeni Petruzzelli et al., 2011). In these value-creating networks, each actor has their own capabilities and resources, and innovation is created by combining those (Faber & Bouwman, 2003). However, geographical distance and technological proximity may hamper the innovative outcomes of inter-firm R&D collaboration (Ardito, Messeni Petruzzelli, & Ghisetti, 2019).

Since the creation and commercialization of new business fields are carried out through linked actors in complex inter-organizational networks (Möller & Svahn, 2009), evolving and changing throughout the invention to commercialization (Aarikka-Stenroos & Sandberg, 2012), a network approach is applied as a primary theoretical perspective of this study. This approach emphasizes the interdependencies of actors, resources, and activities as the key component and major force of change in the network (e.g., Håkansson & Johanson, 1992). More specifically, this study follows the notions of strategic net approach (Möller & Rajala, 2007; Möller & Svahn, 2009), stating that network relationships with divergent actors can be intentionally developed and orchestrated. These two approaches are integrated with research on sustainability transitions (e.g., Geels, 2004; Köhler et al., 2019; Smith et al., 2010) to understand the diffusion of sustainable innovations within industry value networks in its broader context of socio-technical regimes and landscape. The sustainability transitions research assumes that the change starts in niches or innovation systems, but under preferable conditions, those niche actors can become mainstream suppliers serving mainstream markets (e.g., Van den Bergh, Truffer, & Kallis, 2011).

In order to define the characteristics of the food packaging plastic value network, which is the empirical context of this study, and to position its current state accordingly, a value-system continuum with three types of strategic nets (Möller & Rajala, 2007) is used as a starting point. These nets (or value systems) can be analyzed and classified based on their goals and the determination of their underlying value-creating systems (Parolini, 1999). At one end of the continuum are stable, well-defined value systems: *current business nets* that have achieved relative stability and a high level of business process specification in their value creation. They involve well-known actors, technologies, business processes, and value activities. In the middle of the continuum are *business renewal nets* that are based on current value-creation systems but are modified through incremental innovation activities, operationalized through multiparty projects, and aimed to improve current offerings or specific parts of their businesses. At the other end of the continuum are *emerging business nets* characterized by radical, discontinuous, and system-wide changes in old value activities, resulting in new technologies, business concepts, or even business fields. The emerging value systems involve great uncertainty concerning the actors, activities, and resources, and thus they require future-oriented thinking as well as dynamic and complex learning processes that cannot be specified in advance.

In this study, the theoretical concepts related to business nets are employed in the following way. The sustainable innovation examined here, a bio-based, biodegradable plastic packaging material, emerges from a R&D project network, which involves a large consortium of private and public actors who aim to develop the new material towards commercialization. The new bioplastic packaging material creates

pressures and possibilities for a current business net, involved in the production and use of conventional plastic packages for food. If the new packaging material can present an improvement to the existing solution from the manufacturers and end users' viewpoint, changes that transform the current business net into a business renewal net might take place. Radical changes that cause discontinuity in the industry could, in turn, lead to the transformation into an emerging business net. Thus, the sustainable innovation aims to be diffused into *a current business net of conventional plastic food packaging*, and we examine the changes to the current business net facilitating the diffusion.

To examine the changes that can facilitate the diffusion of sustainable innovation in an existing value network, we use a three-level approach, that is based on the extant research on the emergence of new business fields within network approach (e.g., Möller, 2010) and sustainability transitions research (specifically the Multi-Level Perspective (MLP)) (e.g., Smith et al., 2010). Möller (2010) presents The Business Field framework describing the layered nature of business fields, which suggests the ways in which established socio-technological structures and institutionalized meanings condition the emergence of innovations. MLP, on the other hand, outlines pathways for using innovation to change the infrastructure and institutions of society (Loorbach, Frantzeskaki, & Avelino, 2017). It argues that transitions come about through dynamic processes within and between three analytical levels (Köhler et al., 2019). By combining these approaches, a theoretical framework is developed to aid in the understanding of the changes restructuring the current food packaging plastic value network.

First, the macro layer can be identified as consisting of slowly evolving and relatively stable socio-technical landscapes, including socio-political characteristics, such as global political arrangements (e.g., EU, UN), nation states, broad political coalitions, and cultural and normative value systems (Möller, 2010). Closely related to this, MPL suggests the exogenous socio-technical landscape developments as the broadest analytical level (Köhler et al., 2019). In other words, transitions are seen as coming about through interactions between landscape developments (e.g., macro-economic and macro-political trends or significant environmental changes) (Gliedt et al., 2018; Kivimaa & Kern, 2016).

Secondly, the socio-technical landscapes are created and modified through socio-technical regimes in the *meso* layer, which present established business fields with simultaneous stability and incremental change driven by the actors' desire to create better value for customers and increasing efficiency in their business (Möller, 2010). Sustainability transitions research views the socio-technical systems or regimes as consisting of multiple elements, for example technologies, markets, user practices, cultural meanings, infrastructures, policies, industry structures, and supply and distribution chains, in which transitions are non-linear, co-evolutionary processes, involving changes in a range of dimensions (Köhler et al., 2019).

Thirdly, a major source of change in the current socio-technical regimes comes from technological niches at the micro level, which consist of networked actors involved in science and technology-based innovation activities (Möller, 2010). Niches are identified within sustainability transitions research as spaces where innovations are created and tested (Gliedt et al., 2018; Kivimaa & Kern, 2016). Niches thus provide important settings for intensive learning that is critical in radical new knowledge creation and that may influence socio-technical regimes (Möller, 2010). One of the key challenges, however, is how to get the niche experiments to scale up and change the regime. Typically, the change starts from individual firms, seeking technological and economic benefits, and it grows to include a more diverse group of actors, moving towards more sustainable, life-cycle-embracing solutions, aiming for ecological and culture-level changes (e.g., Hansen, Grosse-Dunker, & Reichwald, 2009).

The discussed three levels (macro/landscape, meso/network/regime, and micro/firm/niche) are important, since the literature suggests that change needs to take place at all levels so that sustainable innovation can finally be realized as a commercialized solution. Thus, we use the concepts of firm, network, and macro as the three main levels to explore changes facilitating sustainable innovation diffusion (Fig. 1). Macro level refers to the wide socio-technical landscape, whereas network level focuses on the value creating industry networks or strategic nets consisting of several inter-related actors. Firm level is the smallest unit of analysis referring to individual firms operating in the focal nets.

Understanding the change required for sustainable innovation diffusion is especially interesting in the value network that is already well-established, such as the food packaging plastic value network examined in this study; therefore, restructuring creates major challenges for technology development and formation of niches (Köhler et al., 2019). Next, the empirical exploration aims to shed light on this.

3. Research methods

This study applies qualitative research methods to analyze the changes in an existing industry value network that facilitates the diffusion of a sustainable innovation. Qualitative methods aim at describing, understanding, and explaining interactions, processes, and meanings that create real-life organizational settings (Gephart, 2004). Hence, qualitative methods allowed the researchers to emphasize the qualities of the entities and holistically explore the changes, enabling the commercialization of sustainable innovation (Denzin & Lincoln, 2008, 8; Gephart, 2004).

The change in an existing industry value network is explored in the empirical context of plastic food packaging, which brings together companies from plastic, packaging, and food industries. Although plastic is a dominating material in food packaging, the environmental problems related to conventional plastics and the urge to dispose food waste are increasingly demanding the industry actors to develop and adopt innovations in packaging with more user- and environmental-friendly attributes. The changes in the existing value network, in which this study focuses on, are brought by such a sustainable innovation, a bio-based, biodegradable plastic packaging material. This material is developed in an R&D consortium, involving universities and other research organizations, as well as commercial feedstock suppliers, plastic film producers, packaging firms, technology providers, and other organizations. The aim of the consortium is to recycle agro-food waste, including potato peels and crustacean shells, into a new biodegradable film with properties that reduce the environmental impact. To prevent food waste, antioxidants and antimicrobial features are added to the material to enhance the shelf life of food products. The new bioplastic innovation aims at competing with conventional plastic packaging in selected products (such as fresh food). As these two materials will exist in parallel in the future, this study examines how the related value network changes.

The primary data was acquired through 18 thematic interviews with 25 informants. Most of the interviewees are individuals from organizations in the R&D consortium or individuals from organizations of the broader food packaging plastic network. The interviewees were selected because of their expertise in the areas of food packaging or bioplastics, and they represented different types of organizations and roles, so that a wide perspective in food packaging and the related networks and industries could be achieved (Table 1). The interviewee selection relied on a snowball sampling (Biernacki & Waldorf, 1981), and the interviews started with individuals from the R&D consortium, from which they extended to include other individuals who are knowledgeable of the food packaging plastic value network and bioplastics. Although the questions slightly varied according to the expertise of interviewees, the general themes in each interview related to 1) the actors, resources, and activities of existing industry value network and the prospective value network, enabling the diffusion of a new bioplastic innovation, and 2) the factors hindering and promoting the diffusion of such an innovation. The interviews were organized between August 2018 and August 2019,

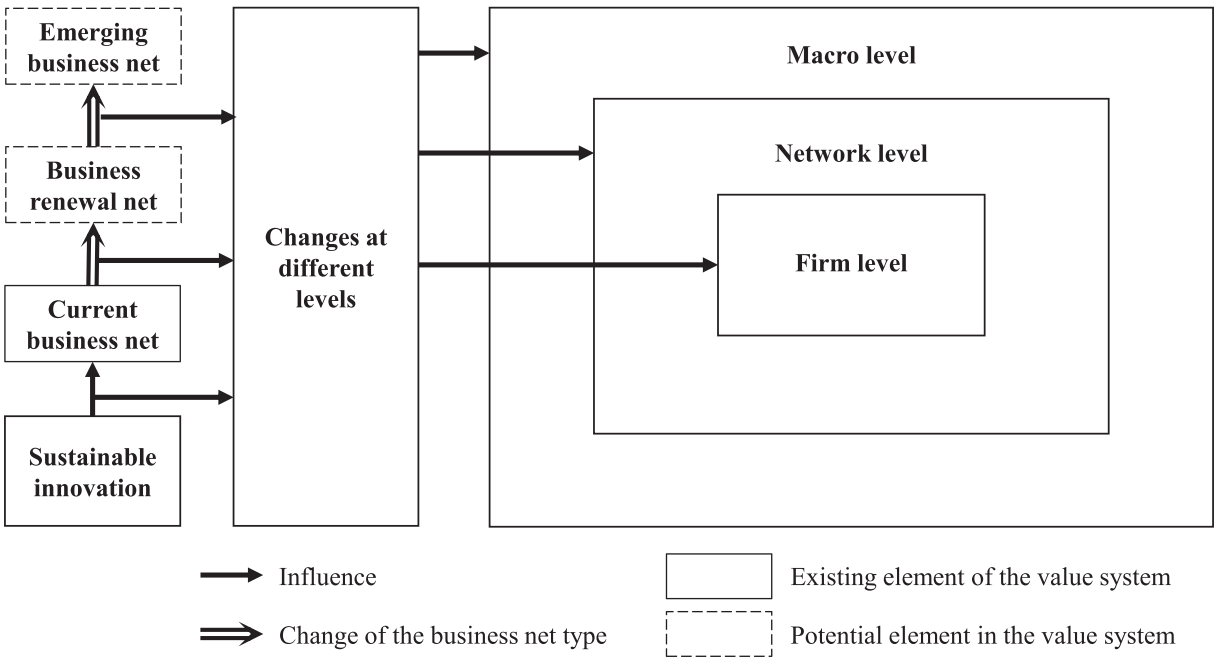

Fig. 1. Levels of change in sustainable innovation diffusion restructuring current business nets.

Table 1
Qualitative interview data.

Informant(s)	Number of informants	Informants' organization type	Interview details
Research Funding Specialist	1	University I	8.8.2018, 40 min
R&D Engineer I	1	Packaging manufacturer	14.8.2018, 90 min
R&D Director & two Product Technicians	3	Brand owner I	4.9.2018, 30 min
Senior Sustainability Consultant	1	Consulting of sustainable development	12.9.2018, 55 min
Innovation Manager	1	Brand owner II	8.10.2018, 60 min
Sustainability Manager & Project Manager	2	Retailer & brand owner	5.11.2018, 70 min
Head of Department of Life Sciences	1	Research institute I	8.4.2019, 45 min
R&D Engineer II	1	Packaging manufacturer	10.4.2019, 50 min
European Project Manager	1	Consulting of agricultural business	16.4.2019, 30 min
Technology Development Manager	1	Brand owner & feedstock supplier	8.5.2019, 80 min
Director of Bioprocesses Area, Researcher & Project Manager	3	Research and innovation center	2.5.2019, 50 min
R&D Project Manager & Researcher	2	Innovation center for plastics	6.5.2019, 55 min
Process Engineer & Team Leader	2	Scaling-up laboratory	20.6.2019, 50 min
Senior Scientist	1	Research institute II	28.8.2019, 90 min
CEO	1	Waste management facility	24.9.2019, 40 min
Associate Professor	1	University II	22.10.2019, 35 min
Professor of Wood and Bionanocomposites	1	University III	23.10.2019, 40 min
Project Manager	1	Technology center for agriculture	30.10.2019, 50 min

and they were finished when the data saturated, as the interviews did not bring any new important information.

The interview data was supplemented by information from five written reports regarding plastic and bioplastic industries, and nearly thirty web pages of the industry-related firms and organizations. This data was gathered to further understand the industry regimes influencing the food packaging plastic value network and to triangulate the findings of the interviews.

The empirical analysis followed the general logic of data reduction, data display, and conclusion drawing (Miles & Huberman, 1994). In practice, the analysis was made in three phases. In the first phase, the changes in the existing food packaging plastic value network that facilitate the diffusion of a new bioplastic were examined from the perspective of the current business actors: *raw material suppliers* (such as chemical companies), (plastic) *material suppliers*, *packaging suppliers*, *brand owners* and *retailers*. These actors form the current rather linear value chain, producing and using plastic film for food packaging. The analysis included the inductive identification of the actors, resources, and activities, and their connections in the existing value network and the changes in these in producing a new bioplastic packaging material in large-scale. Thereafter, the existing and new, emerging or proposed, networks were compared with each other to identify the differences between them and to increase understanding of the changes at a network-level that can enable the diffusion.

In the next step, the data was reread to inductively identify the barriers that hinder or emerging opportunities that could facilitate the actors of the current value network to adopt the more sustainable food packaging. This strengthened the identification of changes needed to the existing value network resulting from surpassing the barriers or seizing the opportunities. In the final phase, the findings were organized into the three levels of change presented in the theoretical framework (firm, network, macro). The interaction between the changes at different levels were further examined and illustrated. These steps of analysis were primarily made by one researcher, but another researcher conducted an analysis as well, and when compared, their findings on the changes were nearly identical, differing only in the names of the changes. Furthermore, the findings were discussed with other researchers and moderated collaboratively in each phase of the analysis to create a mutual understanding of them.

The empirical analysis first describes the industry regimes that influence the existing food packaging plastic value network and then, from the viewpoint of focal actors, describes the implicated changes in the existing network related to adopting the new material. Attention is paid to identifying new or changed actors, resources, activities, and their connections. This focal actor-level presentation is then combined to provide a network- and macro-level analysis and to show how the interaction between these levels can facilitate the diffusion of the sustainable innovation in the food packaging plastic value network.

4. Empirical analysis

4.1. Industry regimes influencing the food packaging plastic value network

Although the food packaging plastic value network is increasingly pressured to adopt new sustainable innovations, their dissemination is problematic because of the established industry regimes. The food packaging plastic value network is affected by the maturity of technology and related business processes that have already been established and are working well, which may hamper the change towards more sustainable packaging materials. The past investments into machinery, manufacturing know-how, processes, and relationships might further decrease the interest of established industry actors, especially plastic material suppliers, to make new investments. As some of these plastic firms are also chemical companies, they tend to be large and well known, and they have a strong position in the network. If these firms do not want to take economic risks related to adopting new materials, especially in the early stages or if they have their connections to the oil industry through ownership, they are powerful enough not to make changes without strong technological and economic benefits.

The food packaging plastic value network includes several established actors, which are connected to each other by long-term collaborations and contracts; a seven-year relationship was described as short in the interviews (Innovation Manager, Brand owner II). This may create barriers for new actors to enter the market by making it difficult to find customers and develop channels for distribution. Specifically, packaging customization may influence the ability of the brand owner to switch their packaging supplier or packaging material in general. Then again, large brand owners can hinder packaging suppliers to invest in answering the specific packaging needs of their other customers, as packaging suppliers often need to offer the same packaging solutions for all their customers to treat them equally in order not to lose them. The collaboration in the food packaging plastic value network is further described as being linear, as its actors are not collaborating beyond their closest partners in the value network and do not have an explicit understanding of whom their partner is collaborating with in the same network.

> We [brand owner] usually work with… the packagers, not the plastic manufacturer. (Innovation Manager, Brand owner II)

> Retailer's negotiating partner is always the food company and they negotiate with their suppliers. (Sustainability Manager, Retailer & Brand owner)

Furthermore, the food packaging plastic network is characterized to be non-transparent, which emerges from the intense competition between plastic firms and the following secrecy related to plastic formulas.

> Because the industry of PE, polyethylene foils, is not a very transparent business. – If you ask for a special occasion, you get what you need to know. So, they will only share with you what is legally obligated to share. Any further questions need a little bit like exercising, maybe a little bit force on them. – They might all look the same, but when it comes to all the additives and other minor components, that's a kind of Coca-Cola formula. They are not willing to share. (Technology Development Manager, Brand owner & Feedstock supplier)

4.2. Changes from value network actors' perspective

The changes as experienced or anticipated by the focal actors in the food packaging plastic value network are discussed next. The changes are examined from the perspectives of the raw material, material, and packaging suppliers, as well as the brand owners and retailers.

Feedstock suppliers are central *raw material suppliers* for bioplastics producers, but they are not an actor in the existing value network involved in conventional plastic food packaging. Potato peels that are utilized to manufacture the new material in question, are a side stream of food processing and their availability seems good, although it is not under the control of plastic *material suppliers*. Using these by-products can generate opportunities for material suppliers through cheaper and more sustainable feedstocks. Food processing firms currently sell their potato peels at a low price for firms who use them to produce animal feed, and there are few such *feedstock distributors* in Europe. However, new ways to valorize such side streams are constantly searched for, which can create opportunities for new feedstock suppliers, but it also might increase the price of the side streams.

> I do not know what types of contracts we [food processing firm] have with this company that kind of picks up the peels and turns them into feed. – I call [it] by-product valorization, because, in the past, it was more like those guys would come to your factory, and they would almost get it for free. So, [we are] looking at how we can valorize some of our side streams. – So, maybe we are kind of bound to a contract at the moment, but it is not like this contract is for life. (Technology Development Manager, Brand owner & Feedstock supplier)

Although new uses for the feedstock can generate an opportunity for a feedstock supplier, the uncertainty related to the availability and price level of agro-food resources can create barriers for material suppliers to invest in developing this type of bioplastic. Generally, brand owners describe it as although there are lots of projects going on developing new bioplastics, material suppliers tend not to participate in these, which emerges from their unwillingness to share their technology and plastic formulas. If large plastic firms are reluctant to answer the specific packaging needs of the food industry, smaller *innovative material developer firms* are suggested to play an important role in developing the material further, as the core of their business is to develop new materials for specific customers. They can either produce small amounts themselves or utilize external production capacity for larger orders.

Besides new feedstock suppliers, the broad diffusion of bioplastic, derived from agro-food waste would require *actors distributing, storing, and processing* the feedstocks. Our data, however, shows that transportation and storing issues can act as a barrier for using agro-food waste in food packaging, because it tends to decay fast and microbial activity can increase the growth of pathogens. The varying quality of feedstock creates challenges for processing them further. In addition, in order to lower the carbon footprint and transportation costs, it is important that central actors are located nearby. Hence, if agro-food waste is used in bioplastic production, strong collaboration between feedstock suppliers, actors distributing, storing and processing feedstocks, and material suppliers would be beneficial in organizing the flows of agro-food waste cost-efficiently and in a sustainable manner. It also needs to be secured that animal feeding is not harmed by allocating potato peels for plastics production.

Because of their strong position in the existing value networks, the role of current material suppliers can however be critical in the large-scale production of bioplastics. When the knowledge of optimizing the production settings for new materials develops, these actors are skillful

enough to produce new biomaterials as technologies and machinery to produce different plastics that are the same. However, time-consuming and costly adaptations are expected if the same machinery is utilized to produce bioplastics. Large and established material suppliers have investment power to make these adaptations into their production or to invest in new processing lines.

> These kinds of companies are really big, and these kinds of companies are really the companies that can drive the innovation [in] plastics to the value chain, industrial chain, because they are producing the materials for the packaging producer. (Innovation Manager, Brand owner II)

However, many of these current actors lack knowledge, for example, in fermentation, to process biomasses from the feedstock, and to manage the related processes. Hence, new actors, *biomass processors*, are needed, at least in the beginning of the change, to develop and operate the processes if the material suppliers are not willing or capable of taking over these activities.

> We need to find somebody who will implement the fermentation and purification processes to obtain PHB. (Associate Professor, University II)

Furthermore, biopolymers require more specific activities in each production and distribution stage compared to conventional plastics (for example, they are difficult to extrude and sensitive to moisture and temperature changes). As this requires large investments into knowledge and learning as well as adaptations to existing processing lines, it is possible that instead of current material suppliers, *specialized bioplastic material suppliers* will have a permanent role in the network.

> We need adaptations, because you need to upgrade the machines. – Always when you upgrade this size of machine to go for large productions… – There are some key points you need to take care of, and you need some time. – Some methodology in the actions that maybe now they do not care about. Now they dry the polyethylene and it is very easy to produce, and when you get it ready, you can store it and forget it.– I think you need to take care of these biopolymers a little bit more in all stages. It is more the behaviors we need to take care of and learn. (R&D Engineer II, Packaging manufacturer)

The data indicates that *packaging suppliers* are in the crossfire of two central actors in the food packaging plastic value network. *Brand owners,* who rarely cooperate with material suppliers, demand new sustainable bioplastic solutions as they face this demand from downstream of the value network. However, based on our data, packaging suppliers experience difficulties of having suitable bioplastic materials from their material suppliers, and they lack knowledge to transform them into reasonably priced packages. The transformation of bioplastics into packages is challenging and packaging suppliers may not be willing to invest in research, which would permit the required development work. However, packaging suppliers are not regarded as the bottleneck actor in the value network.

> We are sure that as soon as the packagers have the possibility of producing, manufacturing, [packages] made of bioplastics, they will offer [them] to us immediately. (Innovation Manager, Brand owner II)

The transition towards the new biomaterial could thus be enabled by stronger connections between material suppliers, packaging suppliers, and brand owners, as these could enhance the important communication about the market demands throughout the food packaging plastic value network and commit to R&D. This is supported by the data, in which large brand owners are shown to already search for potential material suppliers with whom to cooperate in the development of new packaging materials. In addition, a direct connection to material suppliers could allow brand owners to make more credible sustainability decisions.

> The market demands bioplastics. – The food industry demands new packaging for this market. – I suppose packaging suppliers demand bioplastics to produce packages. – I am not very sure if they [packaging suppliers] realize that bioplastics are so important for the business. (Innovation Manager, Brand owner II)

> It [non-transparency] does raise some questions. – If we [brand owner] as a business want to develop more sustainable packaging, we need to know the baseline… For that, you need to have a full understanding of the composition of your foil. – You want to know if you proclaim that your packaging is fully recyclable, because of the base material is fully recyclable, but you do not know what kind of additives are blended into it, then you are walking a little bit on thin ice. (Technology Development Manager, Brand owner & Feedstock supplier)

As many of the large material providers have been slow to provide bioplastics, the interest of brand owners to have a new bioplastic package for a specific purpose could, however, require collaboration with the innovative material developer firms that are willing to invest in the development of new material formulas and applications and do medium-scale production. This type of development is critical as functionality limitations and higher costs are identified as barriers for adopting new bioplastic packaging materials, although there are interested brand owners. Furthermore, the addition of natural antimicrobial agents into the new bioplastic packaging interests brand owners as well as *retailers,* because it can bring an opportunity to extend the self-life of food products, responding to the growing trend of active packaging aimed to decrease food waste. Furthermore, the use of bioplastic, derived from agro-food waste, is an opportunity to improve brand-owners' and retailers' brand image, as it is an interesting story to impart.

However, the required market pull that would demand brand owners and retailers to make real changes to their packaging is just emerging and developing. Although *consumers* are highly interested in sustainable development and are increasingly requiring environmental-friendly solutions, there are misunderstandings related to different forms of bioplastics and the ways of recycling or disposing of them.

> People really do not get the difference, do not know that – polymer can be biobased or biodegradable, so people are not informed of this, so they just say, oh yeah, this looks better and buy that. (R&D Engineer I, Packaging manufacturer)

Sustainability education could thus be beneficial in the diffusion of the sustainable innovation. Such education is already taking place by large brand owners and retailers who cooperate with *environmental associations* and *universities* in this matter. Retailers should, however, more strongly connect with brand owners and other actors in the value network to mediate the demands of consumers and to influence the environmental actions of the entire food packaging plastic value network.

> Many of these sustainability issues are not solved if we just work with them alone. It is the collaboration within the value network that is important. – In solving problems, forming new procedures, different industries can collaborate, not just retailing, but the food industry, environmental service providers, and chemical companies. –Then there are some associations guiding and advising consumers… (Sustainability Manager, Retailer & Brand owner)

In order to minimize the environmental impacts further and to solve the problems in disposing and recycling bio-based, biodegradable plastic packages, new *end-of-life service providers* might be needed. Some interviewees mention that in order to treat biodegradable plastics

effectively and sustainably, and to secure the high-quality process for recyclable plastics, there should be separate waste streams for bioplastics. The biodegradation of biodegradable plastics currently requires special conditions to happen properly, even in industrial composting. This is why current industrial facilities may not be capable or willing to accept such bioplastics. In addition, stronger interaction between end-of-life service providers and material suppliers could facilitate the development of new materials and related technologies to reduce waste and to support compostability.

Lastly, because of the described problems in the transition towards more sustainable packaging, different types of regulations and incentives become critical. This is because although firms are searching for more sustainable solutions, they are also waiting to see what happens with the regulations related to using plastic in food packaging and many actors choose to be more reactive than proactive. This illustrates the strong role of *policymakers* and regulations in diffusing sustainable innovations in food packaging.

> Companies are trying to get in the market to be aware of what is going on. Just in case, [if] they need to go that way. – The bioplastics have not really reached the market, but companies are trying to invest a little bit in that, just in case [that] legislation changes or consumers demand it. (R&D Engineer I, Packaging manufacturer)

By combining the discussed changes, we can see the changes at the network level. Fig. 2 summarizes the changes in the existing activities, resources, and actors and resulting relationship structures, as well as new actors with new activities, resources, and the relationship connections. These network-level changes are suggested to facilitate the diffusion of the sustainable innovation in the existing food packaging plastic value network to transform agro-food waste into the new type of bio-based biodegradable plastic food packaging, reducing food waste, and the sustainable end-of-life treatment for the packaging.

4.3. Interaction of changes at firm, network, and macro levels

The changes to existing industry value networks that facilitate the diffusion of a sustainable innovation take place at three interrelated levels: firm, network, and macro. At the *firm level*, it is important that there are changes related to opportunities emerging from the innovation. Firms *recognizing* these *opportunities* can enable sustainable innovation diffusion throughout the food packaging plastic value network. In the upstream of the value network, the opportunities are accelerated by new actors who are required to perform new activities or bring new resources into the bio-based plastic production, because these create new economic benefits, emerging from using agro-food side streams. Downstream, the new packaging material can assist in reducing food waste and bring other social benefits. Sustainable innovations can further create new business opportunities for actors in the end-of-life services.

The new opportunities are critical because of the high barriers regarding the diffusion of sustainable innovation in an established value network. For example, in the food packaging plastic value network, where the technology is mature and well-working, different economic and social benefits might be required to persuade actors. The need for recognizing new opportunities is, however, different at different parts of the value network, and it is not obligatory that everybody recognizes a new opportunity. The opportunity recognition is the most critical for actors upstream of the value network because of their strong position in the network and because of the barriers and scale of the changes they might need to make into their processes and existing relationships. Therefore, material suppliers are especially important actors. To scale up the production of bio-based, biodegradable polymer, material suppliers might need to form new relationships and adjust their production

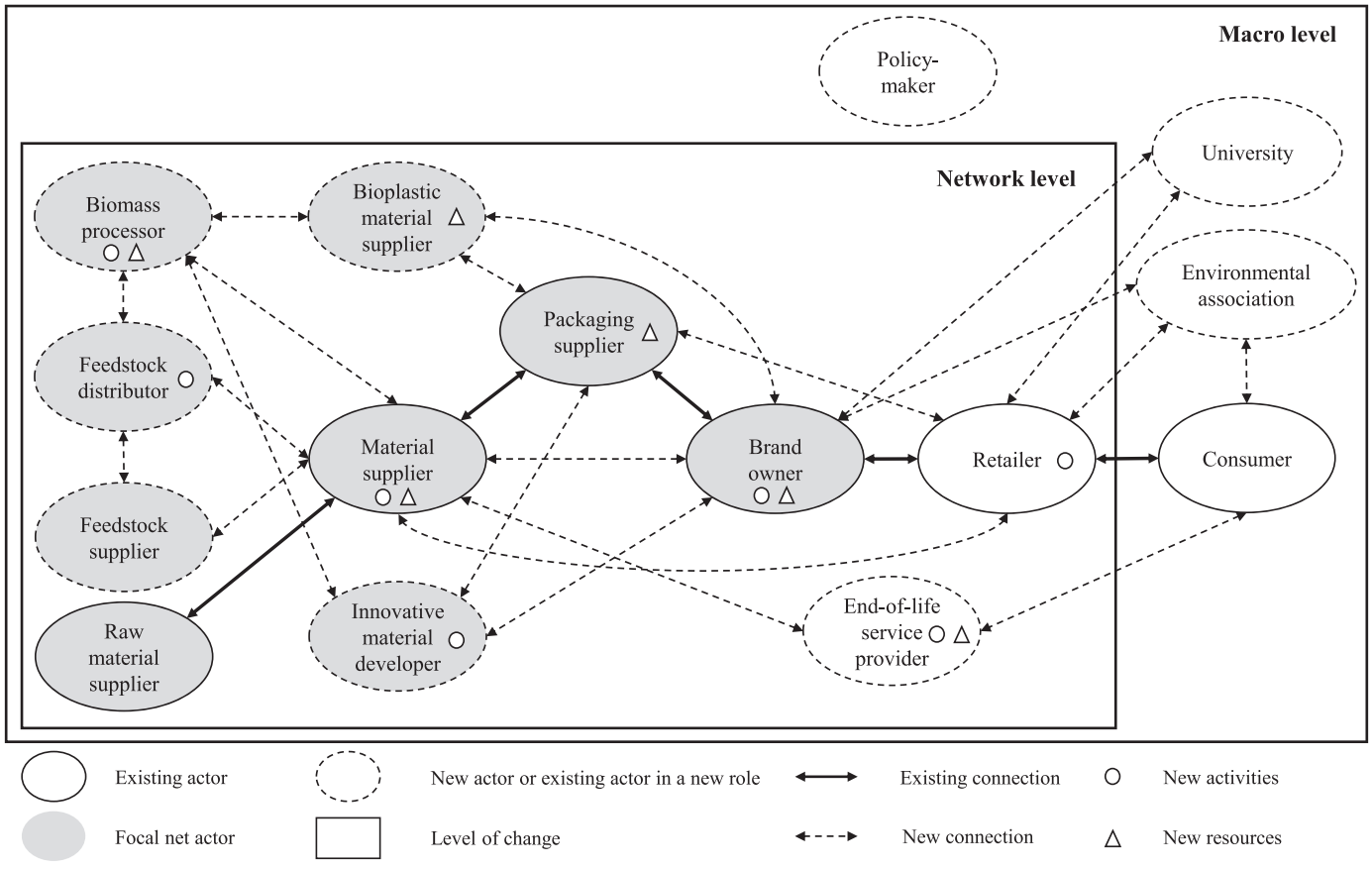

Fig. 2. Changes facilitating the diffusion of bio-based, biodegradable plastic solution in the food packaging plastic value network.

processes.

At the *network level*, *new resources* and *value activities* are important in facilitating the transition towards a new type of biomaterial. Specifically, new resources and activities related to agro-food waste and distributing and processing it for large-scale production and managing the end-of-life processes are relevant. These can be provided by existing network actors or *new actors* entering the market, which would lead to *new connections* between existing and new actors. Similarly, packaging suppliers and brand owners can cooperate with innovative material development firms to develop the material further as well as specialized bioplastic material suppliers to produce such a material if conventional material suppliers are reluctant to make changes to their processes. New connections between existing actors can further enhance the possibility of restructuring the existing industry value network by breaking its non-transparent and linear structure.

In terms of facilitating the diffusion process, *a networked type of collaboration*, in which different actors are more holistically connected and influenced by each other, is suggested to be beneficial, as it is expected to be more powerful than the influence created by individual actors. It has been identified that at the network level, *focal nets,* and key actors in them, play a critical role in facilitating the diffusion of sustainable innovation in an existing value network. As discussed, this might require that the firms identify the collaboration to create new business opportunities. These changes are however challenged by the long-term collaboration and contracts, which might engender barriers for the diffusion even if the demand for sustainable innovations would start to emerge. To summarize, the transition towards bio-based, biodegradable plastic could be facilitated by changes in existing relationship structures in the food packaging plastic value network in both directions – upstream and downstream.

At the *macro level*, the *political framework* and the increasing demand of *consumers* can push and pull firms to identify the firm-level opportunities of sustainable innovations. That is, in food packaging, which is influenced by the regimes of different industries, the large actors are powerful enough to remain with the existing technologies if there are no external drivers pushing them to adopt sustainable packaging innovations. In addition to regulations and incentives, sustainability education can give firms an important framework for doing business, but at the same time increase the understanding and awareness of consumers related to bioplastics and their environmental impacts.

Fig. 3 recaps the described changes at firm, network, and macro levels and shows how the changes at different levels influence each other. The changes are required at each level to facilitate the diffusion process. For example, although it is suggested that a more networked type of collaboration is critical, the interest of actors to cooperate is influenced by the opportunities individual firms recognize will be received from the collaboration, and the other way round; changes in relationship structures might engender new opportunities at the firm level. The network-level changes can then influence the macro level by restructuring the political framework by lobbing the changes to regulations and increasing the market awareness for new sustainable innovations. Similarly, politicians and consumers can force and encourage firms to make sustainable decisions; at the same time as firms are actors in the value network, the macro-level pressure is transformed into the network level as well.

5. Conclusions and implications

5.1. Main results and contributions

This study has addressed the challenge of reducing food waste by examining the changes to existing industry value networks that can facilitate the diffusion of sustainable innovation in food packaging. The innovation in question is a new bio-based biodegradable plastic used in food packaging to better preserve the food and to recycle food waste. As an answer to the research question, the major facilitative changes were described at three levels: *recognizing new business opportunities* at the firm level, *restructuring of existing value networks*, and macro-level actions *creating supportive regulative framework* and *increasing market demand*. These changes were detailed and brought together to depict the way they are interacting with each other through these three levels. Based on the findings, the following conclusions are presented.

First, the findings show that the diffusion of sustainable innovations to an existing value network is largely facilitated not only by the changes

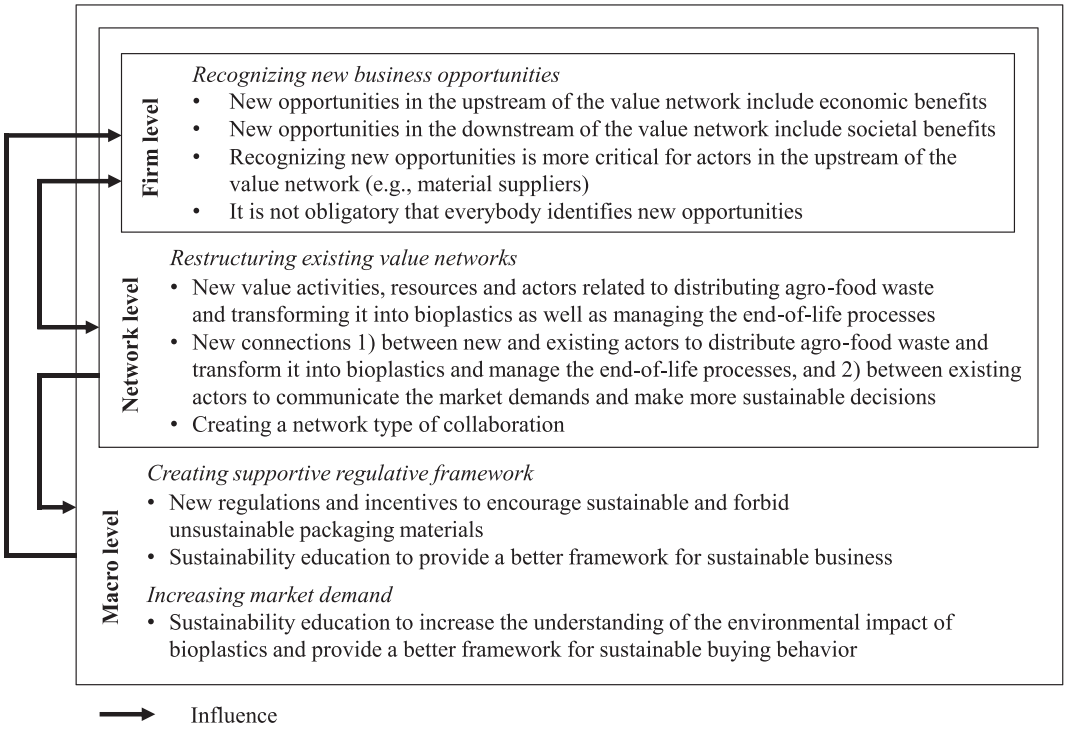

Fig. 3. Changes facilitating sustainable innovation diffusion in the food packaging plastic value network.

at the firm and at the business network level, but also by the changes at the macro level, leading to an interactive chain of changes at these three levels. For example, in sustainable innovations, answering the environmental and social concerns is central, thus emphasizing the role of consumers, regulators, and non-profit organizations in influencing the demand and new business opportunities, as they both push and pull the changes facilitating the diffusion. That is, firm-level changes or strategies are not sufficient to guarantee the realization of sustainability effects of the innovations, since all activities in the network and along the life cycle of the innovation matter. Therefore, we propose the following:

P1. In diffusing sustainable innovations into existing value networks, network and macro-level analysis of necessary changes and their connections is needed beyond the firm-level examination.

This proposition gives rise to three contributions. Firstly, previous research has primarily emphasized the firm level and the role of powerful actors in the sustainability transitions (Gliedt et al., 2018; Lupova-Henry & Dotti, 2019). Our findings support these studies by recognizing that new business opportunities are critical for individual firms. However, by also describing the network and macro-level changes and the interplay of these changes with the firm-level changes, our study extends the existing understanding of diffusion of sustainable innovations. Secondly, previous research has stressed the importance of collaboration between various actors of the related network and the need for understanding of temporal and relational aspects in research (Aka, 2019). The present study contributes to this line of research by describing the conditions arising from the identified changes for such collaboration between different actors within existing networks. Thirdly, the present study answers the call for more research on the new connections in the internal and external contexts of sustainable innovation, enabling the change towards sustainable systems (Adams et al., 2016; Baya & Gruman, 2011; Xavier et al., 2017) by identifying the key actors, resources, and activities as well as the connections between them (both existing and new) to diffuse sustainable innovations.

The second conclusion of the present study relates to the logics of restructuring of the value networks by showing how the diffusion of a sustainable packaging material implicates complex restructuring of the existing value network, in terms of new actors, resources, activities, and connections, as well as changes to the existing networks. Specifically, changes to the existing industry regimes are called for to engender a networked type of collaboration and transparency, needed to support the diffusion of sustainable innovations in the existing value network. Thus, the following proposition is made:

P2. Changes facilitating the diffusion of a sustainable innovation into an existing value network are interconnected at firm, network, and macro levels, resulting in a slow and complex process including transforming industry regimes.

The conclusion extends the sustainability transitions research highlighting the firm- and niche-level changes that take place in initiating industry re-orientation (e.g., Köhler et al., 2019). The diffusion of sustainable innovation has been described as a process that relies on ecosystem actors integrating resources into a constantly evolving value proposition that also restructures the network (Trischler, Johnson, & Kristensson, 2020). The present study sheds light on such restructuring by showing that the diffusion of sustainable innovations is based on a networked type of collaboration, in which individual industry actors are holistically connected and influenced by each other. Such network collaboration is identified to increase the transparency of sustainability information, which has been acknowledged in the literature to be important at firm and supply chain levels (Wognum, Bremmers, Trienekens, van der Vorst, & Bloemhof, 2011), as well as at a governmental level (Galera et al., 2014). Our findings support these studies as we find that without such transparency of information among the network actors, the sustainability claims of new materials, for example, are difficult to verify. The findings are also in line with the existing knowledge on strategic nets according to which in innovation diffusion, complex webs of knowledge and technological bonds between firms with complementary skills and resources are required (Möller & Rajala, 2007; Möller & Svahn, 2009).

As the third conclusion, the present study demonstrates that to decrease food waste, the improvements in food packaging also to be considered holistically and in terms of related value networks. Even though bioplastics that use organic waste or side-streams as a feedstock appear as a promising way to recycle food waste, there are economic, environmental, and societal concerns that might slow down their diffusion to broader use. This study pointed out the sustainability of the feedstocks, the dispersed availability and varying quality of the feedstocks, the special conditions required for distributing and storing the feedstock and the bioplastic material, and that such feedstocks may already have current uses, such as animal feed. Also, even if food-preserving features are combined with a new bio-based biodegradable plastic food packaging, the amount of food waste and the final environmental effect is largely affected by consumers and the end-of-life services. Thus, we propose that:

P3. To prevent food waste, sustainable innovation in packaging utilizing agro-food waste and food-preserving features requires the consideration of the whole life cycle of the packaging and related value network changes.

Previous research on food waste reduction has examined the issue from various viewpoints (see e.g., Gollnhofer, 2017; Papargyropoulou et al., 2014), often pointing out the role of consumers and retail (e.g., Parfitt et al., 2010); recently, food packaging has also received increasing research attention (see e.g., Ketelsen, Janssen, & Hamm, 2020; Licciardello, 2017). The present study extends this existing knowledge by identifying the changes to existing industry value networks that can facilitate the diffusion of sustainable innovation in food packaging.

5.2. Implications for managers and society

The findings of this study provide implications for a variety of actors. First, firms aiming to develop and commercialize sustainable innovations need to build understanding of their own business environment not only at firm level, but also at network and macro levels. The diffusion of the innovation will likely cause and be influenced by interconnected changes at all these levels. This seems to be important particularly in industries with established networks, technologies, and regimes, and in industries where regulation has a strong role in guiding businesses, such as in the food packaging industry. The need to understand the connected changes at all three levels is essential for non-business actors as well, such as universities and other research institutions. However, for such actors, it might be challenging to gain insight into industry networks, and thus they would benefit from cooperation with central industry partners and associations to identify the most suitable application possibilities and to diffuse their innovations.

Secondly, due to the systemic nature of sustainable innovation diffusion, the managers of firms in existing value networks need to adopt a strategic and network-based approach. Identifying how the sustainable innovation may impact the firm's existing and future business is important and largely linked to the impacts of the innovation to other actors in the network. The innovation might create new business opportunities for some and negative effects for other actors in the network. In order to diffuse a sustainable innovation, the related system needs to be ready to manage the full life cycle of the innovation. Broad collaboration, both horizontal and vertical, and between firms and non-profit and public actors, is often needed to develop the system. Such collaboration can enhance both the achievement of sustainability effects, transparency, and business opportunities for firms. Collaboration impacts even industry regimes and legislation, and it can modify complex

infrastructures that are needed for diffusing new sustainable innovations. For example, the food packaging industry brings together actors from the plastic industry, packaging industry, food industry, retail, public sector, and waste management. For packages in which recycling streams are well organized and functioning, change of the packaging material might require changes to the material loop and technologies of many actors. However, when diverse actors and their interests collide, win-win solutions might be rare, at least in the short term, but the broader sustainability pressure that is felt by all actors can act as an overarching element.

Thirdly, for legislators and regulators, this study highlights the importance of mechanisms that support a still developing market. Both policy push and policies and activities facilitating the company-driven business opportunity recognition are needed. The public sector could have a stronger role in facilitating the multi-sectoral collaboration around sustainable innovations. Also, the public sector could clarify and boost the market for business actors and consumers alike, advancing the creation of unified standards, measures, and certificates for sustainable materials, and by educating consumers. This can eventually change the consumption habits, which, in turn, attracts companies to adopt sustainable innovations. Finally, clear communication and discussion about the forthcoming legislation, how it relates to existing legislation, and its schedule would reduce the uncertainty of business actors, also supporting the market of and investments in sustainable materials.

5.3. Limitations and future research avenues

The present study employs data depicting the changes that could facilitate the diffusion of bioplastics as a packaging material innovation within the food industry and in its existing value networks. Therefore, the findings should be considered as specific to the food packaging value chain setting and applicable in other industry contexts with similarities in existing value networks and industry regimes. For example, in food packaging, various health and consumer protection regulations, and a long-standing dominant role of conventional plastics and related network actor bonds may influence the actors' attitudes towards the innovation and the sustainability diffusion in the networks. In addition, as our data includes informants from different national contexts, cultural aspects may affect the behaviors of the actors, and we acknowledge the potential role of the culturally related communication inconsistencies as well.

In terms of sampling of informants in our empirical data, the study has limitations to be considered. Although the collected data was appropriate in terms of shedding light on the perceptions of the different value network actors, industry regimes, and anticipated changes due to the diffusion of the innovation, yet the varying contexts from which the expert interviewees perceived the phenomenon may have influenced their perceptions. Specifically, the interviewees who participated in the R&D consortium developing the innovation could have had a more positive attitude towards the innovation in question than the other interviewees.

In terms of future research avenues, first, more research is called for to unravel the challenging process of diffusing sustainable innovations, especially into an established value network with strong existing regimes. This study brings forward some of these challenges from the viewpoint of restructuring the existing network; but for example, understanding of ways to motivate actors in such industries to collaborate for sustainability is important. It was apparent in our data that mere technological break-throughs were not enough to induce innovation diffusion, but actor-level perceptions seemed to play crucial role as well. As many innovations are introduced to such existing networks, instead of forming new emerging business nets, more knowledge on the matter is important.

Secondly, restructuring appears to be a highly complex and multi-layered phenomenon of which more knowledge is needed, especially in terms of its origins. Our data hinted that these origins of restructuring can be of various types, ranging from events, individuals, agendas, or collaboration. By revealing these triggers of change, more could be understood of the mechanisms through which more sustainable innovations could be brought into well-established industry networks.

Thirdly, the understanding of the interconnectedness of the different levels and the way this is materialized at the actor-level perceptions needs further elaboration in the future. Our data gave a strong indication that within industries with established industry regimes and interorganizational relationships, the changes demand actor-level and entrepreneurial opportunity recognition for the network-level diffusion to take off. Future research on the conditions of opportunity recognition, especially in the context of sustainable innovation and existing industry regimes, is very much needed, and moreover, how policy instruments could facilitate that process.

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Declaration of Competing Interest

None.

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