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The role of strategic alliances in creating technology legitimacy: a study on the emerging field of bio-plastics

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Abstract

The aim of this study is to analyze the role of strategic alliances in creating legitimacy for an emerging sustainable technology. The literature has identified different ways in which alliances create legitimacy for firms, but it has failed to address the legitimacy of technologies. This paper contributes to this literature by identifying technology-sourced market legitimacy, technology-sourced social legitimacy and technology legitimacy. It focuses on the case of bio-plastics, which is emerging as a sustainable technology due to pressures towards environmentalism in the chemical industry. The analysis is based on a database that we constructed using secondary sources, and which contains information on 105 alliances in the field of bio-plastics over the period 1990-2013. The results show that firms increase their market and social legitimacy by accessing the sustainable technology of an alliance partner, by collaboratively developing a sustainable technology, or by providing the technology of a partner with access to customers and production capacity. Alliances also promote the desirability and appropriateness of a technology (i.e. technology legitimacy) by supplying multiple applications of the technology to an expanding number of markets, by exercising their signaling role, and by acting as institutional entrepreneurs. Alliances that stimulate technology-sourced market and social legitimacy are often bilateral and inter-firm alliances that produce and market sustainable technologies. In contrast, alliances that stimulate technology legitimacy are multilateral and inter-organizational alliances in the pre-competitive and R&D stages of the value chain.

1. Introduction

The plastics industry has been under pressure to develop sustainable innovations since the 1990s (Hoffman, 1999). Plastics are produced mainly from petroleum and represent the largest field of application for crude oil (Siracusa et al., 2008; Shen, 2011). The durability of plastics and the use of oil as feedstock are causing environmental problems related to waste, use of non-renewable resources, and climate change (Ren, 2003; Shen et al., 2009; Chadha, 2011). In response to these concerns, different bio-plastics have emerged as sustainable innovations (Iles and Martin, 2013). Bio-plastics are bio-degradable and/or are made from bio-based raw materials (Álvarez-Chávez et al., 2012; Iles and Martin, 2013). They can reduce the dependency of plastics production on oil, and can contribute to solving environmental issues.

Recent studies highlight the importance of collaboration and strategic alliances for the success of sustainability innovations, including the transition to bio-plastics (e.g. Lozano, 2008a). Strategic alliances are voluntary collaborations between organizations that involve the exchange, sharing or co-development of products, technologies, and services to pursue a common set of goals or meet critical business needs (Gulati, 1998; Lin, 2012). Key advantages of alliances include the acquisition and exchange of complementary resources, and entry into new markets and technologies (Jolink and Niesten, 2012; Rothaermel and Boeker, 2008). Alliances facilitate the development of sustainable

innovations, because these innovations depend on capabilities and resources that are spread over organizations from different industries (Van Tulder et al., 2015). The widespread adoption of bio-plastics in consumer goods will require alliances between firms from the chemical and food industries.

In the emerging field of bio-plastics, it is not only important that firms enter into alliances, but these alliances also need to create legitimacy for the new technology in order to facilitate the transition. Legitimacy is a generalized perception that organizations or activities are desirable or appropriate within an institutional setting (Seo and Creed, 2002; Dacin et al., 2007; Thornton and Ocasio, 2008). Innovations require legitimacy to succeed, and this is especially relevant for sustainable innovations (Rennings, 2000; Hekkert et al., 2007). As sustainable innovations often compete with existing technologies, a crucial challenge for organizations developing sustainable innovations is to convince others of the desirability and appropriateness of these innovations within the existing institutional setting (Rennings, 2000; Kishna et al., 2015). This is difficult in emerging fields, because technological standards that evaluate the sustainable innovation have not yet emerged (Garud and Rappa, 1994).

Firms can attempt to obtain legitimacy through collaborations, for instance by connecting to firms with a legitimate image or by collaboratively establishing social norms (David et al., 2013). The performance and survival of firms is strongly dependent on securing legitimacy (DiMaggio and Powell, 1983; Ruef and Scott, 1998), and public benefits will only be realized when sustainable innovations obtain legitimacy and are diffused throughout society. Dacin et al. (2007) have categorized different types of legitimacy that firms can obtain by entering into alliances, including market, social, investment, alliance, and relational legitimacy. The source of legitimacy is often the alliance partner's legitimacy in a market or the social image of the partner. These types of legitimacy address the legitimacy of a firm, but the legitimacy of technologies has not received much attention in the literature (Dacin et al., 2007; Lin, 2012; Wassmer et al., 2014).

In this paper we combine insights on alliances and institutional theory in order to enhance our understanding of the legitimating roles of alliances in the context of sustainable technologies. The main contribution of this paper lies in the identification and definition of three new types of legitimacy: technology-sourced market legitimacy, technology-sourced social legitimacy and technology legitimacy. In the first two types of legitimacy, firms aim to enhance their legitimacy in a market or their legitimacy as a socially responsible firm. They use the sustainable technologies of the alliance as a source of legitimacy, and not the image, reputation or experience of a partner. In the case of technology legitimacy, alliance partners do not aim to enhance their own legitimacy but the legitimacy of the sustainable technology.

In order to study these types of legitimacy, we have built a database on alliances in the field of bio-plastics using data from press releases and industry journals. The database contains information on 105 alliances over the period 1990-2013. The results show how alliances aim to obtain the three forms of legitimacy in the context of the sustainable technology. We also demonstrate that alliances that stimulate these forms of legitimacy differ from other alliances in terms of the organizational background of alliance partners, the number of alliance partners and the business functions of the alliance in the value chain.

The following section discusses the literature on legitimacy and alliances. Section 3 presents the research setting and the data collection methods. Section 4 discusses our results, and section 5 concludes this paper.

2. Theoretical framework

2.1 Legitimacy of organizations in an institutional context

The success of organizations depends on their legitimacy, and thus on their desirability and appropriateness as judged by others. For instance, the ability of organizations to get access to markets and critical resources is strongly influenced by their legitimacy (Seo and Creed, 2002; Dacin et al., 2007; Greenwood et al., 2011). Whether organizations are judged to be legitimate or not depends on the institutional context that surrounds the organizations and in particular on the dominant values, norms, and beliefs that are present in the institutional context (Greenwood et al., 2011).

In mature organizational fields, institutional demands are predictable, and legitimacy is gained from complying with well-known institutional pressures. However, organizations often introduce innovations in emerging fields, and this makes it especially challenging to obtain legitimacy for new technologies. Emerging fields are characterized by a large degree of uncertainty, because institutional demands are not clear, making it difficult to determine how to obtain legitimacy (Greenwood et al., 2011). These fields portray strong conflicts between institutions, as organizations battle to prioritize institutions that support their interests and beliefs. Organizations that envision new institutional arrangements and undertake actions to realize these new arrangements are often referred to as institutional entrepreneurs (DiMaggio, 1988; Battilana et al., 2009). These organizations undertake actions aimed at generating institutions in order to become legitimate.

However, our understanding of organizational responses of institutional entrepreneurs to different institutional settings remains selective (Pache and Santos, 2010; Greenwood et al., 2011). Institutional entrepreneurship entails diffusing new institutional visions and is a collective process. Despite this, there is a tendency in the literature to focus on the efforts of individual institutional entrepreneurs as heroes of change (Suddaby, 2010; Klein Woolthuis et al., 2013). There has been some attention for the relation between collaborations and institutional entrepreneurship (Philips et al., 2000; Lawrence et al., 2002). We attempt to expand on these insights by looking at strategic collaborations as a potential source of legitimacy and institutional entrepreneurship.

2.2 Strategic alliances and legitimacy

The legitimacy-based functions of alliances have not received much attention (Dacin et al., 2007; Lin, 2012), but it has been argued that legitimacy can be an outcome of alliances. By enhancing legitimacy, alliances can yield other benefits, such as an increased access to markets, the ability to attract resources and improvements in firm and alliance performance. Dacin et al. (2007) propose that five distinct types of legitimacy needs of firms play an important role in alliance formation, as is shown in table 1. A strategic alliance may provide market, relational or social legitimacy for a focal firm, investment legitimacy for a firm's activities, and alliance legitimacy for the alliance in general. Firms can enter into an alliance with one or several of these five legitimacy goals in mind.

Table 1 – Legitimizing roles of strategic alliances from Dacin et al. (2007)

	Market legitimacy	Relational legitimacy	Social legitimacy	Investment legitimacy	Alliance legitimacy
Definition	Rights and qualifications to conduct business in a particular market	Worthiness to be a partner	Conformity of the firm to societal rules and expectations	Worthiness of the business activity	Validity or appropriateness of strategic alliances
Motive for entering alliance	To increase one's legitimacy in a geographical or product market	To increase one's legitimacy as a good partner	To increase one's legitimacy as a socially responsible firm	To increase the legitimacy of the business activity	To legitimate alliance use
Source of legitimacy	Partner's legitimacy in the market	Relationship with partner	Partner's social image	Partner's support and confidence in the business activity	Isomorphism
Target	Governments, suppliers, customers	Potential ties	Public interest groups, local communities, customers	Board of directors, corporate executives, venture capitalists, shareholders	Other organizations, parent firms

First, a firm can enter into an alliance to enhance its rights or qualifications to operate in a specific market. This need for market legitimacy can be driven by a lack of experience, reputation or performance of a focal firm. Market legitimacy differs from entering into an alliance to access a market; the former is related to being perceived as having the right to operate in a specific market by connecting to a partner with a legitimate image, while the latter is related to using distribution or marketing channels from a partner to gain access to specific markets. Second, a firm can be motivated to enter an alliance to demonstrate it is a worthy partner. This need for relational legitimacy can be driven by a lack of history as a good alliance partner and a necessity of alliances in the future to enhance the firm's performance. Third, firms may enter into alliances to increase their image as a socially responsible organization, by partnering with firms that have a good social image. Fourth, an alliance can serve to legitimate the business activities of participating firms in the eyes of corporate insiders. This need for investment legitimacy will be high when the business activity has not been adopted by the focal firm or by other organizations in the past. Finally, in some circumstances the legitimacy of alliances as a form of business transaction needs to be established. This need for alliance legitimacy will likely be strong in fields that do not have a history of alliance use while acceptance of the alliance form is important for achieving other types of legitimacy.

2.3 Alliances and legitimacy of sustainable technologies

The framework by Dacin et al. (2007) focuses on creating legitimacy for firms, but it underemphasizes two crucial aspects of legitimacy in the context of sustainable technologies. First, when firms aim to enhance their legitimacy in a specific market or their social image by entering into an alliance, the increase in the firm's legitimacy is directly and specifically linked to the sustainable technology (section 2.3.1). Second, it is not only relevant to enhance the legitimacy of firms and alliances, but also the legitimacy of the sustainable technology itself (section 2.3.2).

2.3.1 Technology-sourced market and technology-sourced social legitimacy

As sustainability has economic and social/environmental dimensions (Lozano, 2008b), we expect that market legitimacy and social legitimacy are especially important in the context of sustainable technologies.

When an innovative sustainable technology is developed, new markets need to be created to sell the technology. As these new markets are being formed, firms may lack some of the relevant experience and reputation, and they may enter into alliances to overcome these shortcomings and increase their market legitimacy. In the case of bio-plastics, large food companies may enter into alliances with firms from the chemical industry with access to technologies to develop, improve, and produce bio-plastics. When we compare this type of market legitimacy in the context of sustainable technologies to the framework by Dacin et al. (2007), we expect that the motive of firms is the same, but the source of legitimacy may be different. Firms aim to increase their legitimacy in a geographical or product market (i.e. motive) but do not use the overall experience or reputation of the partner as a source of market legitimacy. Instead, firms may relate their right and qualifications to conduct business in a specific market to the technology of the partner or to the technology developed in the alliance. We may refer to this type of legitimacy as ***technology-sourced market legitimacy***.

In addition to market legitimacy, social legitimacy is likely to be relevant in the context of sustainable technologies. Firms may wish to enter the business of sustainable technologies to increase their legitimacy as a socially responsible firm, and again they may use alliances to pursue this motive. For instance, firms that sell products and services to end users may wish to improve the sustainability of their supply chain, by including more sustainable inputs in the production process or by increasing the sustainability of the products' packaging. They improve their social legitimacy by entering into alliances with firms that possess the technologies to produce sustainable inputs and packaging. In this way, firms can relate conformity to social rules and expectations to the technology of the partner or to the technology developed in the alliance. The adoption or development of sustainable innovations can signal that a firm is being responsible and is complying with social expectations. We may refer to this type of legitimacy as ***technology-sourced social legitimacy***. While the motive of this type of legitimacy is the same as in the framework by Dacin et al. (2007) (i.e. increase one's legitimacy as a socially responsible firm), the source of the social legitimacy is different: the source is not necessarily the partner's social image but the sustainable nature of the partner's or the alliance's technology.

2.3.2 Technology legitimacy

In the context of innovative sustainable technologies, it is not only important that firms increase their legitimacy but also that the new technology obtains legitimacy by being perceived as legitimate by a broad spectrum of actors. Innovation studies stress the importance of legitimacy creation for innovations in the eyes of outsiders and increasing legitimacy of a new field in general (Hekkert et al., 2007). It is, however, very challenging for sustainable innovations to obtain legitimacy in an emerging field. In mature fields firms can use the field's standards, norms, and technologies to obtain legitimacy (Aldrich and Fiol, 1994; Zimmerman and Zeitz, 2002). In emerging fields, technological standards are often unclear, and innovations compete with existing technologies that are adapted to the institutional setting (Eisenhardt and Schoonhoven, 1996; Garud et al., 2002). A crucial challenge for organizations developing sustainable innovations is to convince others of the appropriateness

and desirability of these innovations relative to how the currently prevailing logics evaluate the innovations (Rennings, 2000; Kishna et al., 2015).

We expect that firms use alliances to demonstrate the worthiness of a sustainable technology to outsiders. Through their signaling role, alliances can support and promote certain technologies, increasing the legitimacy of these technologies. This implies that legitimacy battles between new and old technologies will take place but also between alternative technological trajectories within a field (Tushman and Anderson, 1986; Garud et al., 2002). Alliances can also function as institutional action takers. They can try to establish new institutions, such as specific standards, that provide guidance with respect to evaluating technologies, and can thereby improve the legitimacy of these technologies (Garud et al., 2002). In this way, alliances take the role of champions, trying to influence the nature of institutional pressures through collective action that supports specific technologies. As such, alliances function as institutional entrepreneurs when they envision new institutional arrangements and undertake actions to realize this new institutional setup (DiMaggio, 1988; Garud et al., 2002; Greenwood and Suddaby, 2006). We therefore argue that alliances can increase **technology legitimacy**, i.e. the desirability and appropriateness of the technology as perceived by actors outside of the alliance.

3. Methods

3.1 Research setting

The global plastics industry has steadily grown since the 1950s, and demand is likely to continue to rise (PlasticsEurope, 2013). Plastics are produced mainly from petroleum and represent the largest field of application for crude oil (Siracusa et al., 2008; Shen, 2011). The first oil crisis in 1973 raised public concern over limited fossil resources (Siracusa et al., 2008). The prospect of feedstock supply insecurities was a first trigger for the plastics industry to start looking for alternative raw materials suited for plastics production. In the period 1980-1990 other environmental issues emerged, and attention was drawn to rapidly increasing amounts of waste and limited landfill capacities (Shen et al., 2009). Two crucial aspects of plastics (i.e. petro-based production and durability) are directly related to these environmental problems (Ren, 2003; Shen et al., 2009; Chadha, 2011).

Following these events, bio-based plastics gained attention as possible sustainable innovations. Bio-plastics are bio-degradable and/or made from bio-based raw materials (Álvarez-Chávez et al., 2012; Iles and Martin, 2013). They are viewed as having the potential to reduce the dependency of plastics production on oil and to contribute to solving environmental issues. A first wave of bio-plastics was introduced to the market in the early 1990s. However, these plastics did not perform as advertised, and bio-plastics became associated with misleading environmental claims and sub-par performance (Iles and Martin, 2013). Related to the attention for climate change at the end of the 1990s and technological developments, a second wave of bio-plastics started in the 2000s (Iles and Martin, 2013). Firms from many different industries, including agriculture and food products, have entered this field.

3.2 Case selection

Within this field, we focus on bio-plastics that are produced for consumer markets and are thus consumed by end users. We also include inputs that are developed to produce these bio-plastics,

such as succinic acid or 1,4-butanediol. We focus on these markets, because the issue of legitimacy is especially relevant in markets in which consumers are deciding on whether the technology is appropriate and desirable. The majority of these bio-plastics are used for durable consumer goods and packaging of consumer durable and nondurable goods. We exclude bio-polymers related to fibers, yarn, and textile, as these are related to different markets. Bio-plastics in medical applications have been excluded for the same reason. We also exclude so-called oxo-degradable plastics. These plastics have been marketed as bio-plastics in the past but are essentially petro-based plastics with additives that enable them to degrade under certain conditions into micro-plastics. However, these plastics have been criticized for not being truly bio-degradable and/or bio-based.

In this paper, we study alliances in the field of bio-plastics and consider a diverse set of alliances, including joint ventures, contractual alliances, consortia, associations, and public-private partnerships. The alliance partners retain their own legally autonomous firms or organizations, meaning that we do not consider mergers and acquisitions as part of alliances (Ménard, 2004; Jolink and Niesten, 2012).

3.3 Data collection and analysis

The data on alliances in the field of bio-plastics is collected from several sources. Following the research suggestion from Wassmer et al. (2014), our secondary data sources are European industry journals, Dutch newspaper articles, press releases, and corporate websites. Data is collected for the period 1990-2013. The starting-point is in line with the first commercial wave of bio-plastics that emerged after petro-based plastics became dominant. Alliances that started but also ended within the time period were also recorded.

It can be argued that many of the data sources, such as industry journals and press releases, present a biased interpretation of events and issues (Hoffman, 1999). However, this output directly influences perceptions of actors in the field. Consider for instance that an alliance is formed with specific goals in mind, but in the press release the only motivation mentioned is obtaining market legitimacy. As this message influences issue interpretation in the field, this bias reflects the attention of the alliance partners (Hoffman, 1999) and is thus exactly the data we need to study. In order to fully capture these effects, multiple news items on each alliance have been studied.

The data sources were scanned for alliances in the field of bio-plastics. The main search terms used were varieties of *bio-plastic*, *bio-polymer*, *bio-based plastic*, *sustainable plastic*, and *renewable plastic* and were combined with terms such as *collaborate*, *cooperate*, *partner*, *joint venture*, and *alliance*. These search terms were used in LexisNexis, Bioplastics Magazine (the only independent trade magazine worldwide dedicated to bio-plastics) and the Green Chemicals blog (a leading blog documenting green developments in the chemical industry). For each alliance that is in line with our definitions of alliances and bio-plastics, we recorded the alliance year, names of alliance partners (and alliance name if applicable), type of alliance, organizational background of partners, business function of the alliance, and types of legitimacy. Two researchers coded the variables used in this study. In a few instances the coding differed between the two researchers, which was resolved by discussing the details of the alliance and collecting more information about the alliance on companies' websites.

3.3.1 Coding legitimacy

The data sources were scanned for the motives for obtaining legitimacy (i.e. the explicitly mentioned legitimacy that partners want to increase) and the sources of legitimacy (i.e. the aspects of the partners that are perceived as providing legitimacy). After a first analysis of all the alliance descriptions, we found types of legitimacy that differ from the ones in the framework by Dacin et al. (2007): the alliances have the same motive (increasing market and social legitimacy of the firm), but use the technology and not the reputation or experience of the partner as a source of legitimacy.

In the case of **technology-sourced market legitimacy**, firms enter into alliances to increase their market legitimacy by using a sustainable technology as the source of legitimacy. We coded alliances as characterized by this type of legitimacy when:

- A firm enters into an alliance to access the technology of its alliance partner, which enables the firm to move into the market.
- The alliance partner provides the technology of a firm with access to more markets / consumers or production capacity.
- Alliance partners collaboratively develop or sell a new technology to access a new market.

In the case of **technology-sourced social legitimacy**, firms enter into alliances to enhance the firm's social legitimacy via a sustainable technology. They often refer to sustainability as part of the firm's strategy, values, vision, objectives, and even their business model. Social legitimacy arguments are related to visibility, impact, or image outside of the direct market and are related to public benefits in general. We code alliances as characterized by technology-sourced social legitimacy when firms use alliances to increase their social legitimacy by:

- Collaboratively developing a sustainable technology
- Accessing the sustainable technology of the alliance partner
- Improving the sustainable technology so that an increasing number of customers can access the technology
- Providing the alliance partner with a sustainable technology access to the firm's production capacity or customer base.

Additionally, we encountered alliances that attempted to increase the legitimacy of specific technologies towards external actors. These have been labeled as alliances that stimulate **technology legitimacy**. This type of legitimacy differs from the technology-sourced market and social legitimacy, but also from the types proposed by Dacin et al. (2007): it is not aimed at increasing the legitimacy of the firm or the alliance but at increasing the legitimacy of the technology itself. We coded alliances as stimulating technology legitimacy when:

- They stimulate the development and production of multiple applications of the technology to facilitate the adoption of the technology in entire supply chains and across different sectors. This may include references to broad technology categories (for instance all PLA plastics, and not one

specific brand), implying that other firms using comparable technologies can benefit from the efforts of the focal alliance.

- They aim to expand the geographical market in which the technology is produced and sold.
- They exercise their signaling role by, for instance, referring to a partnership with a large and well-known company that has adopted the technology, or by informing and educating the public on the importance of the technology.
- They act as institutional entrepreneurs by developing and implementing standards, certificates or labels for the technology, or by lobbying for new legislation and regulation.

3.3.2 Coding alliance attributes

We also coded attributes of the alliances that promote the different forms of legitimacy, such as the type of alliance (whether it is bilateral or not), the organizational background of the partners and the business function of the alliance, in order to understand whether there exist differences between alliances that stimulate legitimacy and those that do not.

Bilateral alliances are alliances with two alliance partners, and multilateral alliances involve more than two alliance partners.

For each alliance we examined the types of organizations involved. The alliance was coded as inter-firm when only private firms are part of the alliance. Alliances that included a state, (local) government, university, NGO, and/or a state-owned firm were coded as inter-organizational alliances.

We coded the three business functions of the alliance, which include R&D, manufacturing, and marketing (Kim et al., 2003). During the coding process, we discovered that several alliances do not pursue any research or develop a new technology, nor do they manufacture or market a product. We refer to these alliances as alliances that are in the pre-competitive stage of business activities.

0. Pre-competition: alliance does not pursue R&D, manufacturing or marketing
1. R&D: alliance carries out research or develops a technology that is specific for the alliance and used in production
2. Manufacturing: alliance starts with the establishment of production capacity
3. Marketing: alliance starts after production phase, focused on bringing products to specific markets

4. Legitimacy in the field of bio-plastics

This section presents the results on alliances that stimulate technology-sourced market legitimacy (section 4.1), technology-sourced social legitimacy (section 4.2) and technology legitimacy (section 4.3) in the field of bio-plastics. In section 4.4, we discuss how alliances that stimulate the different types of legitimacy differ from other alliances in our dataset, in terms of the organizational background of alliance partners, the number of partners, and the business functions of the alliance in

the value chain. Appendices 1 and 2 offer a short description of the data sources and the firms that are referred to in the results.

4.1 Technology-sourced market legitimacy

In 40 alliances in our dataset firms aim to obtain market legitimacy by using technology as a source of their legitimacy. We identified three ways in which firms pursue technology-sourced market legitimacy.

First, they aim to increase their legitimacy in a market by accessing the technology of their alliance partner. An example of this type of legitimacy is the alliance between Bayegan and Myriant, in which Bayegan accesses Myriant's technology. The CEO of Bayegan comments on the alliance: *"Increasingly, our customers are seeking high-performing, renewable chemicals, like bio-succinic acid. Through our partnership with Myriant, Bayegan can reliably deliver an innovative, in-demand product that adds significant value for our customers"* (Myriant, 2013). Another example is the alliance between packaging producer Oerlemans Plastics BV and FKUR (a company that has developed packaging based on PLA blends), through which Oerlemans can better serve a market by accessing the technology of FKUR. The press release on the alliance mentions the following: *"Responding to the increase in the demand for biodegradable and compostable films and packaging Oerlemans Plastics is cooperating with FKUR in Germany in order to better serve the upcoming organic market"* (Bioplastics Magazine, 2009a).

Second, a firm may aim to increase its market legitimacy by providing the technology of its alliance partner with access to markets or production capacity. In September 2012 Sulzer Chemtech entered into an alliance with NatureWorks: *"This project has been a natural marriage of each company's assets, focused on a subset of NatureWorks' patented process technology to bring both new capacity and new products to the market"* (NatureWorks, 2012a). By offering production capacity Sulzer could increase its legitimacy with this alliance: *"Additional work was done in our test center with two primary benefits in focus – increased capacity and product extension. The project development provided an exciting professional and technical opportunity for us to show our capabilities for this type of application"* (NatureWorks, 2012a).

Third, alliance partners may also increase their legitimacy by collaboratively developing or selling a technology to access a market. For instance, Altuglas International and NatureWorks have signed a global co-marketing agreement. *"Through the collaboration, Altuglas International and NatureWorks will pool resources to accelerate the introduction of these new high performance biopolymer alloys into the market. By combining our respective reputations and strengths in biopolymers and acrylics, NatureWorks and Altuglas International will co-market clear materials that offer a complete package of innovative product performance"* (NatureWorks, 2012b).

4.2 Technology-sourced social legitimacy

In 41 alliances in our dataset firms attempt to obtain social legitimacy based on a sustainable technology. In several alliances, firms pursue social legitimacy by collaboratively developing a sustainable technology or by accessing the sustainable technology of the alliance partner. BASF and Purac have collaboratively developed a technology that can serve as an input in the production of bio-plastics. The research director of BASF comments on the alliance with Purac and emphasizes

BASF's sustainability goals: *"Our strategy clearly focuses on innovations for a sustainable future. The development of a succinic acid production process based on fermentation in cooperation with Purac is a good example of this strategy being put into practice"* (BASF, 2012). In the alliance between H.J. Heinz and The Coca-Cola Company, Heinz obtained access to the PlantBottle technology developed by Coca-Cola for use in its own products. Heinz argues that *"this partnership is a great example of how businesses are working together to advance smart technologies that make a difference to our consumers and the planet we all share"* (Bioplastics Magazine, 2011). Heinz links the use of Coca-Cola's technology to making a difference for the planet. A similar line of reasoning is found in other alliances. De Ster, a Belgian firm producing plastic cutlery for the aviation industry, argues that they entered into an alliance with Biotec based on *"a desire to work on our social responsibility"* (NRC Handelsblad, 1996). De Ster refers to the compostable technology of Biotec as a means to be socially responsible; the company reinforces this by stating that the technology is currently more expensive than conventional plastics.

Firms may also obtain social legitimacy by increasing the number of customers that can access their sustainable technology or by offering production capacity and a customer base to the sustainable technology of an alliance partner. The alliance between BASF and Purac illustrates this: *"Our cooperation with Purac to produce biobased succinic acid is a perfect example of how we enable our customers in many industries to develop sustainable solutions"* (BASF, 2012). Another example is the alliance between The Coca Cola Company and Avantium, which is a company that has developed a technology to produce PEF bottles. Avantium can improve its legitimacy with its sustainable technology by entering into an alliance with Coca Cola that offers large production capacity and a large number of customers: *"PEF is 100% biobased and when commercialized will be fully recyclable. We are very excited about the co-development phase we are entering with The Coca-Cola Company to continue the development of PEF and make this new material ready for mass production and recycling. Their leadership and experience in commercializing biobased materials make them a great partner to work with as we commercialize this exciting new material"* (Avantium, 2011).

4.3 Technology legitimacy

Establishing technology legitimacy plays a prominent role in alliance formation in the bio-plastics field. In total, we identified 63 alliances with a technology legitimacy driver. These alliances aim to support or demonstrate the desirability or appropriateness of a sustainable technology to actors outside the alliance.

The majority of these 63 alliances stimulate technology legitimacy by developing or producing multiple applications of the technology, thereby allowing for an increased adoption of the technology. The press releases refer to alliances that allow *"for bio-based product solutions in applications that were previously difficult to address"* (NatureWorks, 2012c) and that *"elaborate on the application of bio-plastics for the entire life cycle"* (Bioplastics Magazine, 2009b). A research analyst of Frost & Sullivan commented on the alliance between Purac and Sulzer Chemtech, and mentioned that *"The companies are lauded for their efforts at realizing a novel, economical polymerization process and their commitment toward commercializing this technology for varied high-performance applications"* (Frost & Sullivan, 2008). This new process will *"enable a more efficient production of different PLA products and will reduce the process and product development time. In addition, the new process requires limited investment and will, therefore, be more affordable,*

significantly lowering the entry barrier for PLA production" (Frost & Sullivan, 2008). This example shows that creating legitimacy for the new technology does not only benefit the alliance partners, but also firms that wish to start producing PLA.

Several other alliances promote technology legitimacy by expanding the markets in which the technology can be sold, thus expanding the number of firms that can produce and sell the technology. The purpose of a collaboration between Avantium and Alpla is *"to create a market pull for PEF, which will de-risk the value chain for other partners like feedstock suppliers, chemical companies, resin producers and recyclers, which are essential to put a new polyester on the market"* (Bioplastics Magazine, 2013). The CEO of Metabolix commented on the alliance between his company and ADM: *"This agreement is a major advance toward our goal of making an array of renewable, eco-friendly alternatives to traditional petrochemical plastics widely available to the global marketplace"* (Metabolix, 2004). These examples illustrate that the alliance partners do not aim for legitimacy of their own firm but for legitimacy of the technology by creating opportunities that also benefit other firms (e.g. lower entry barriers, de-risking the value chain).

A few press releases refer to the signaling role of alliances in which famous alliance partners promote the legitimacy of a new technology. Gevo and The Coca-Cola Company entered into an alliance to develop the PlantBottle, which is packaging made from plant-based materials. The CEO of Gevo mentioned that *"New technologies need champions. The Coca-Cola Company is in a unique position to drive and influence change in the global packaging supply chain with this development. You cannot ask for a better champion than one of the world's most respected and admired consumer brands"* (Gevo, 2011). This example clearly shows that the image of the partner is a source of legitimacy for the technology.

In addition to this signaling role, alliances also build technology legitimacy by promoting discussion on the technology and by spreading knowledge on how the technology can be used. Two examples can be given of alliances with the explicit aim to create awareness of the technology. *"The Bioplastic Feedstock Alliance was formed by some of the world's leading consumer brand companies as a precompetitive, multi-stakeholder forum focused on increasing awareness around the environmental and social performance of potential feedstock sources for bio-based plastics"* (Bioplastic Feedstock Alliance, 2015). *"DPI [The Dutch Polymer Institute] provides a unique platform for generating awareness of new technology, in which participating industrial companies, competitors in the market place, communicate on a pre-competitive basis to trigger innovation"* (Dutch Polymer Institute, 2015).

Finally, alliances may act as institutional entrepreneurs by lobbying for new legislation, regulation, standards and certificates for the technology. For instance, *"European Bioplastics closely monitors, discusses and contributes to relevant EU legislation concerning the European bioplastics industry"* (European Bioplastics, 2015). *"The Belgian BioPackaging association obtained with targeted lobbying work some important modifications to the local waste legislation and supported the creation of the first law in Europe that defines the terms compostable, home compostable and degradable in the soil"* (nova-Institute, 2015). The promotion of technologies towards external actors and the creation of supporting institutions are also observed in several brand-owner alliances. The most prominent ones are the Plant PET Technology Collaborative (partners: Coca-Cola, Ford, Heinz, Nike, Procter & Gamble) and the Bioplastic Feedstock Alliance (partners: Coca-Cola, Danone, Ford, Heinz, Nestle,

Nike, Procter & Gamble, Unilever, WWF). The first builds on Coca-Cola’s PlantBottle technology. This alliance “seeks to drive the development of common methodologies and standards for the use of plant-based plastic including life cycle analysis and universal terminology. The brands will then promote these standards with the expectation that they will be endorsed and used worldwide by both PTC and non-PTC members” (PlasticsToday, 2012). In other words, this alliance tries to legitimate technologies by establishing institutions. These institutions may influence how actors outside the alliance evaluate the desirability and appropriateness of the technologies.

4.4 Attributes of alliances that stimulate legitimacy

Table 2 illustrates that alliances aimed at technology-sourced market legitimacy and technology-sourced social legitimacy are more often inter-firm alliances (i.e. alliances between private firms), and bilateral alliances (alliances between two firms). These alliances often focus on business functions that are characteristic of later stages of the value chain, such as manufacturing and marketing. We have compared these two groups of alliances to the remaining set of alliances in our dataset and find that the two groups differ significantly from the other alliances. An analysis of variance shows that there are significant differences (at the 1% level for each of the three attributes) between alliances that stimulate technology-sourced market legitimacy (n=40) and the remaining alliances (n=65). An analysis of variance also shows that there are significant differences between alliances that stimulate technology-sourced social legitimacy (n=41) and the other alliances (n=64) at the 1% level for organizational background and alliance type, and at the 5% level for the business function. This means that we can identify alliances that promote technology-sourced market or social legitimacy as separate groups of alliances that differ from other alliances.

Table 2 – Alliances that stimulate technology-sourced market and social legitimacy

	Technology-Sourced Market Legitimacy (n=40)	NO Technology-Sourced Market Legitimacy (n=65)
Organizational background	Inter-firm alliances: 95% Inter-organizational alliances: 5%	Inter-firm alliances: 66% Inter-organizational alliances: 34%
Alliance type	Bilateral: 90% Multilateral: 10%	Bilateral: 65% Multilateral: 35%
Business function	Pre-competition: 0% R&D: 30% Manufacturing: 37.5% Marketing: 32.5%	Pre-competition: 12.3% R&D: 49.2% Manufacturing: 23.1% Marketing: 15.4%
	Technology-Sourced Social Legitimacy (n=41)	NO Technology-Sourced Social Legitimacy (n=64)
Organizational background	Inter-firm alliances: 95% Inter-organizational alliances: 5%	Inter-firm alliances: 66% Inter-organizational alliances: 34%
Alliance type	Bilateral: 88% Multilateral: 12%	Bilateral: 66% Multilateral: 34%
Business function	Pre-competition: 0% R&D: 34.1% Manufacturing: 41.5% Marketing: 24.4%	Pre-competition: 12.5% R&D: 46.9% Manufacturing: 20.3% Marketing: 20.3%

Alliances that stimulate technology legitimacy differ in certain respects from alliances that do not stimulate legitimacy of a technology in the field of bio-plastics (see table 3). They are more often multilateral and inter-organizational alliances, meaning that the number of alliance partners is higher and the partners include governments (at state or local level), universities and research institutes,

and NGOs. They often take the form of associations, consortia, or public-private partnerships. The alliances that stimulate technology legitimacy also differ from other alliances, because they are formed in a pre-competitive stage, meaning that they do not only pursue R&D, manufacturing or marketing. In this pre-competitive stage, the alliances are concerned with lobbying for new legislation, regulation, standards, and certification for the new technology. They also aim to increase awareness and inform consumers of the benefits of the new technology. An analysis of variance shows that there are significant differences between the two groups of alliances (those that stimulate technology legitimacy and those that do not) but only at the 10% level for alliance type and business function.

Table 3 – Alliances that stimulate technology legitimacy

	Technology Legitimacy (n=63)	NO Technology Legitimacy (n=42)
Organizational background	Inter-firm alliances: 75% Inter-organizational alliances: 25%	Inter-firm alliances: 81% Inter-organizational alliances: 19%
Alliance type	Bilateral: 68% Multilateral: 32%	Bilateral: 83% Multilateral: 17%
Business function	Pre-competition: 12.7% R&D: 41.3% Manufacturing: 23.8% Marketing: 22.2%	Pre-competition: 0% R&D: 42.9% Manufacturing: 35.7% Marketing: 21.4%

5. Conclusions

This paper focused on the role of alliances in creating legitimacy for sustainable technologies. On the basis of an analysis of 105 alliances in the field of bio-plastics over the period 1990-2013, we identified three new types of legitimacy.

In technology-sourced market legitimacy, firms enter into alliances to access a sustainable technology and thereby increase the firm’s legitimacy in a market. In technology-sourced social legitimacy, firms use a sustainable technology in an alliance to improve their image as a socially responsible firm. These two types of legitimacy differ from existing types, because they explicitly use a technology and not a partner’s reputation or experience, as a source of legitimacy. Firms aim to obtain these two types of legitimacy in different ways: by accessing the sustainable technology of an alliance partner, by collaboratively developing the technology, or by providing the technology of the partner with access to customers and production capacity. These alliances are often bilateral and inter-firm alliances that operate in later stages of the value chain, such as production and marketing.

A third form of legitimacy is technology legitimacy, with which alliance partners aim to enhance the legitimacy of the sustainable technology itself and not necessarily the legitimacy of the firm. Our results show that alliances promote the desirability and appropriateness of a technology to others (i.e. technology legitimacy) by developing and producing multiple applications of the technology for an expanding number of markets, by exercising their signaling role, and by acting as institutional entrepreneurs. Alliances that stimulate technology legitimacy differ from other alliances, because they are more often multilateral and inter-organizational alliances. They operate in the pre-competitive stages and focus on promoting standards, certificates, labels, and legislation for the new technology.

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Appendix 1. Data sources of quotes mentioned in section 4.

Reference	Title	Data source
Avantium, 2011	Avantium and The Coca-Cola Company sign partnership agreement to develop next generation 100% plant based plastic: PEF.	avantium.com/news/2011-2/Avantium-and-The-Coca-Cola-Company-sign-partnership-agreement-to-develop-next-generation-100-plant-based-plastic-PEF.html
BASF, 2012	BASF and CSM establish 50-50 joint venture for biobased succinic acid.	www.basf.com/documents/corp/en/news-and-media/news-releases/2012/10/P444_BASF_Purac_2012_Oct4_e.pdf
Bioplastic Feedstock Alliance, 2015	Bioplastic Feedstock Alliance, 2015. Who we are.	www.bioplasticfeedstockalliance.org/who-we-are/
Bioplastics Magazine, 2009a	Bioplastic films from the Netherlands.	www.bioplasticsmagazine.com
Bioplastics Magazine, 2009b	Biodegradable bags project in Thailand.	www.bioplasticsmagazine.com
Bioplastics Magazine, 2011	Ketchup in biobased PET.	www.bioplasticsmagazine.com
Bioplastics Magazine, 2013	New partner joins PEF bottle development.	www.bioplasticsmagazine.com
Dutch Polymer Institute, 2015	Dutch Polymer Institute, 2015. Key facts.	www.polymers.nl/About/Keyfacts
European Bioplastics, 2015	European Bioplastics, 2015. Activities.	en.european-bioplastics.org/about-us/activities/
Frost & Sullivan, 2008	PURAC, Sulzer Chemtech and Synbra Technology jointly awarded Frost & Sullivan polylactic production technology innovation of the year award.	www.frost.com/prod/servlet/press-release.pag?docid=177397034
Gevo, 2011	The Coca-Cola Company and Gevo Partner to Develop and Commercialize 100% Renewable Plastic Bottles.	ir.gevo.com/phoenix.zhtml?c=238618&p=irol-newsArticle&ID=1640177
Metabolix, 2004	Metabolix and ADM Enter Strategic Alliance to Commercialize PHA Natural Polymers.	ir.metabolix.com/releasedetail.cfm?releaseid=211091
Myriant, 2013	Myriant and Bayegan Group Partner to Commercialize Renewable Chemicals.	www.myriant.com/media/press-releases/myriant-and-bayegan-group-partner-to-commercialize-renewable-chemicals.cfm
NatureWorks, 2012a.	NatureWorks broadens Ingeo product portfolio with Sulzer proprietary production equipment.	www.natureworksilc.com/News-and-Events/Press-Releases/2012/09-05-12-Sulzer-equipment-for-increased-Ingeo-production
NatureWorks, 2012b	NatureWorks, 2012b. Altuglas International and NatureWorks launch worldwide marketing collaboration for new high performance alloys incorporating Ingeo biopolymers.	www.natureworksilc.com/News-and-Events/Press-Releases/2012/12-11-12-Arkema-NatureWorks-collaborate-on-high-performance-alloys-with-Ingeo-biopolymer
NatureWorks, 2012c	NatureWorks and BioAmber form joint venture to commercialize new bio-based polymers.	www.natureworksilc.com/News-and-Events/Press-Releases/2012/02-16-12-NatureWorks-BioAmber-Joint-Venture-AmberWorks
nova-Institute, 2015	Belgian Biopackaging VZW/ASBL.	www.bio-based.eu/iBIB/pdf/8.pdf
NRC Handelsblad, 1996.	Disney composteert voedselafval.	NRC Handelsblad, 1996
PlasticsToday, 2012.	Five major U.S. brands collaborating on plant-based PET.	www.plasticstoday.com/articles/Five-major-US-brands-collaborating-on-plant-based-PET-0605201202

Appendix 2. Description of firms mentioned in section 4.

Firm name	Major industry (based on SIC code)	Short firm description
ADM	Food products	One of the world's largest agricultural processors and food ingredient providers; it also produces biofuels.
Alpla	Paper	Leading company in packaging. Sells plastic bottles, caps, and preforms.
Altuglas International	Chemicals	Leading company in polymethyl methacrylate technology. Sells Plexiglas products (a sturdy transparent plastic).
Avantium	Research and development	Technology company specialized in the area of advanced catalytic research. Developed YXY technology to convert plant based materials into bioplastics.
BASF	Chemicals	Largest chemical producer worldwide. Operates in different markets; has named its segments chemicals, plastics, performance products, functional solutions, agricultural solutions, and oil & gas.
Bayegan	-	International distributor and trader of petrochemicals, chemicals, steel products, and other commodities.
Biotec	-	Develops and produces sustainable bioplastics made from plant-based resources. Sells customized thermoplastic materials under the brand name BIOPLAST.
The Coca-Cola Company	Food products	Multinational beverage corporation. Manufacturer, retailer and marketer of beverage concentrates and syrups. Developed PlantBottle, bottle partially made from plants.
De Ster	Plastics products	Supplies aviation and rail industry with packaging for beverages and hot meals. Also sells cutlery and trays.
FKuR Kunststoff	Rubber and plastics products	Leading producer of customized bioplastics. Sells a range of biobased and compostable resins under different brand names (such as Bio-Flex).
Gevo	Chemicals	Renewable chemicals and biofuels company. Developed bio-based alternatives to petroleum-based products using synthetic biology and chemistry.
H.J.Heinz	Food products	Multinational food processing company. Mostly know for ketchup brand of the same name.
Metabolix	Plastics products	Advanced biomaterials company. Sells sustainable solutions to plastics industry, including PHA biopolymers and biobased chemicals.
Myriant	Chemicals	Produces bio-based chemicals. Sells different products, but most expertise in bio-succinic acid.
NatureWorks	Chemicals	Started as Cargill research project looking for innovative uses of carbohydrates of plants as feedstock for plastics. One of the largest players in bioplastics. Sells bioplastics under Ingeo brand name.
Oerlemans Plastics BV	Rubber and plastics products	Producer of plastics and packaging. Sells films and packaging to horticulture, agriculture and retail.
Purac	Chemicals	Currently operates under new name Corbion. Global market leader in lactic acid. Sells bioplastics in markets: packaging & disposables, consumer goods, consumer electronics, automotive.
Sulzer Chemtech	Industrial and commercial machinery	Leading player in fields of process technology and separating towers. Sells pumps and rotating equipment in industries such as chemical processing, oil and gas, power generation, and pulp and paper.