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The role of online information-sharing platforms on the performance of industrial symbiosis networks

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ABSTRACT

From technical perspective, an important condition for developing industrial symbiosis (IS) is the match between waste supply and demand. Such a match is hampered by lack of information among companies, i.e., demand (supply) for waste exists but firms producing (requiring) that waste are not aware of such a demand (supply). Despite online information-sharing platforms are proposed to support the creation of industrial symbiosis networks (ISNs), related environmental and economic benefits are not in-depth investigated. This paper firstly aims to fill this gap.

Although up-to-date literature recognizes lack of information-sharing as an IS barrier, in-depth analysis about the impact of sensitive information-sharing on the operations of IS is not addressed. This paper secondly aims at filling this gap.

In this paper, we design an agent-based model to simulate the emergence and operations of self-organized ISNs in three scenarios: (1) no information-sharing platform; (2) a platform where companies provide information about their geographical location and the type and quantity of produced and required wastes; (3) a platform where companies provide sensitive information about the costs of operating IS. These scenarios are simulated in a numerical case study involving two kinds of IS businesses: (1) marble residuals used in concrete production; (2) alcohol slops used in fertilizer production.

Results show that online platforms increase the economic and environmental performance of ISNs. Findings help practitioners to understand the importance of information-sharing and to clarify whether the information they consider as 'sensitive' is really sensitive or it is non-sensitive information that facilitates business-making.

1. Introduction

Industrial symbiosis (IS) is a subfield of industrial ecology that engages separate industries in a collective approach to competitive advantage, involving physical exchange of materials, energy, and services (Chertow, 2000). In particular, wastes generated by one firm can be used by other firms to replace production inputs or be exploited to generate new products. By replacing inputs with wastes, firms can gain economic advantages because of enhancing production efficiency and, at the same time, create environmental and social benefits for the entire collectivity (Fraccascia et al., 2017a; Jacobsen, 2006; Yu et al., 2015; Yuan and Shi, 2009).

The European Commission explicitly recognizes the usefulness of the IS approach to boost resource use and production efficiency and recommends the implementation of such a practice (European Commission, 2015, 2011). Furthermore, several studies indicate that IS can be a useful approach for companies to reduce their CO_2 emissions (Hashimoto et al., 2010; Liu et al., 2017; Sun et al., 2017). As a result, policymakers of many countries have introduced the IS practice in their environmental agenda (Costa et al., 2010; Husgafvel et al., 2013; Mirata, 2004; Van Berkel et al., 2009).

An industrial symbiosis network (ISN) is a network of firms among which IS relationships exist (Fichtner et al., 2005). These networks can be designed by adopting a top-down approach, such as the eco-industrial park model (Heeres et al., 2004; Lambert and Boons, 2002), or emerge from the bottom as the result of a spontaneous and self-organized process undertaken by the involved firms (Chertow and Ehrenfeld, 2012; Doménech and Davies, 2011). Despite empirical cases show that both models can be successful, in recent years scholars seem to have converged in considering the self-organized approach as the most promising one. However, self-organized ISNs are underdeveloped in terms of practical applications compared to theoretical developments in the field. This is due to the low emergence rate of new ISNs and the low sustainability of existing ISNs over the long period (Chiu and Yong, 2004; Paquin et al., 2015). From the technical perspective, the most relevant condition for the development of sustainable IS relationships

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over the long period is the match between supply and demand of wastes (Yazan et al., 2016b). In fact, the lack of this match reduces the economic benefit that firms gain from the IS practice (Albino et al., 2016), which is the first driver attracting firms to adopt such a practice (Lyons, 2007). The mismatch between waste supply and demand quantities can be because of: (1) the lack of firms producing (requiring) a given waste for which demand (supply) exists (Alfaro and Miller, 2014; Eilering and Vermeulen, 2004; Fichtner et al., 2005); (2) the lack of information, i.e., demand (supply) for a given waste exists but firms producing (requiring) that waste are not aware of such a demand (supply) (Aid et al., 2017; Chertow, 2007; Golev et al., 2015; Sakr et al., 2011; Zhu and Cote, 2004). In addition, apart from potential savings from waste discharge costs (for the waste producer) and traditional resource purchasing cost (for the waste receiver) companies need to deal with additional costs to implement and operate IS. These costs are waste treatment costs, transportation costs, and transaction costs whose sum should be lower than the potential savings so that companies are motivated to initiate IS. Driven by the uncertainty on supply-demand match, also the costs and benefits of IS might fluctuate over time dynamically. This represents a barrier against implementing sustainable IS-based business and this paper aims to understand how such uncertainties can be reduced via adopting online information-sharing platforms.

Information communication technologies are claimed to play a critical role in solving both these problems (Heeres et al., 2004; Kincaid and Overcash, 2001). By using online platforms, firms can easily share information among themselves about their geographic location, the type and the amount of both produced and required resources, as well as their availability to start new IS relationships. Such a strategy can facilitate collaboration among firms helping them to discover IS opportunities (Park et al., 2016).

However, so far the extent to which online platforms can support IS relationships has been not in-depth investigated by the literature because assessing the real contribution of these tools is problematic (Grant et al., 2010). In fact, through observing the adoption of online platforms *a posteriori*, it is difficult or even impossible to understand which IS relationships took place thanks to the platform and which IS relationships would have been created even without the platform.

In IS-based business models, companies' willingness-to-share information with each other plays a critical role to launch the initial cooperation phase. Although information-sharing might intuitively increase the trust between companies, it might also be interpreted as the fact of revealing sensitive data about production recipe of products of the company. Furthermore, IS might require some basic information about the available/requested resource quantities, waste quality, details about the waste content such as chemical or physical characteristics, potential costs of treatment and transportation, etc. The sensitivity of such data is mainly decided by company managers who develop an information-sharing strategy in markets. However, as recognized in the IS literature (Ashton, 2008; Chertow, 2007; Sakr et al., 2011), information-sharing has a catalyzer role in facilitating the implementation of IS which has different dynamics than classical business models. Therefore, the questions pop up: 'What is sensitive information for a company?', 'Which type of information is non-sensitive for a company to implement IS-based cooperation?' and 'Is 'the sensitive information' really sensitive enough to motivate the limitation for its non-disclosure?'

In this paper, self-organized ISNs are studied from a complex system perspective approach to understand the role of (sensitive and non-sensitive) information-sharing via a communication platform on the performance of ISNs. In particular, we adopt the agent-based modeling, which is one of the most suited technique to study complex systems (Axelrod, 1997). In ABMs, each agent is characterized by a given set of goals and actions to accomplish and a given set of rules of social engagement, driving its interactions with other agents and the environment (Bonabeau, 2002; Weiss, 1999). Such an approach permits to investigate the system dynamics in a way that analytical models cannot do. In fact, the complex system behavior spontaneously emerges from the interactions among the agents and between the agents and the environment, rather than to be defined by the modeler (Macal and North, 2010). We design an agent-based model (ABM) which simulates the spontaneous creation and the operations of an ISN in three different scenarios: (1) basic scenario, where no communication platform is adopted; (2) a communication platform provides non-sensitive information about the geographical location of each firm and the type and quantity of produced and required wastes; and (3) a communication platform provides sensitive-information about the costs of operating IS, in addition to those provided by the second scenario. Physical and monetary flows among firms are assessed by adopting the Enterprise Input-Output (EIO) approach. These three scenarios are simulated in a numerical case study that concerns an ISN composed of marble, concrete, alcohol, and fertilizer producers. By comparing results from different scenarios, the paper quantitatively assesses the contribution of the adopted platform in supporting ISNs.

The paper is organized as follows. Section 2 presents the theoretical background on ISNs and role of information platforms to support IS-based businesses. The ABM for ISNs is developed in Section 3. Section 4 describes the scenario setting in the ISN case under investigation. Section 5 provides the simulation results. Findings are discussed in Section 6 and conclusions are presented in Section 7.

2. Theoretical background

This section is divided in two sub-sections. Sub-section 2.1 summarizes the Industrial Symbiosis Networks (ISNs) from a complex systems approach while Sub-section 2.2 focuses on the literature about the role of information platforms supporting the formation and operation of IS.

2.1. Studying self-organized ISNs: a complex systems approach

A wide part of the literature recognizes self-organized ISNs as complex adaptive systems (CASs) (Ashton, 2009; Côté and Hall, 1995; Liwarska-Bizukojc et al., 2009; Romero and Ruiz, 2013; Seuring, 2004). CASs are networks of agents that emerge over time into coherent forms through interaction, without any singular entity or central control mechanism deliberately managing the overall system (Dooley, 1997; Holland, 2002, 1995). The adaptiveness of these systems depends on their ability to change over time, creating new forms of emergent order consisting of new structures and patterns. These changes are not externally imposed on the system but they are due to the self-organization of the agents, which are able to autonomously interact among each other, in order to increase their fitness with the environment (Goldstein, 1999). The existence of interconnected agents with different attributes and actions, self-organization, adaptation, emergence, nonlinearity, and path dependence are recognized as the main properties of CASs (Arthur, 1994; David, 1994; Goldstein, 1999).

Framing the ISNs as CASs means that ISNs are the result of a self-organized process, where any generic firm autonomously makes the decision to establish IS relationships with other firms (i.e., to send/receive wastes to/from other firms) without any deliberate planning performed by a central entity, aimed at increasing its economic performance and gaining competitive advantage (Ashton, 2011; Esty and Porter, 1998; Lyons, 2007; Yuan and Shi, 2009). In fact, by exchanging wastes for primary inputs, firms can enhance their production efficiency (Fraccascia et al., 2017a), which allows them to reduce waste disposal costs and input purchase costs. However, these economic benefits are eroded by additional costs stemming from IS relationships, in particular waste treatment costs, waste transportation costs, and transaction costs (Esty and Porter, 1998; Sinding, 2000). Waste treatment costs depend on the technical substitutability between wastes and inputs. In fact, in some cases, additional processes can be required to