Toward the creation of novel food waste management systems: a network approach

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Abstract

In light of the global significance of food waste, a greater focus on improving food waste management strategies is called for. Implementing such management strategies requires a better understanding of stakeholder relations. This paper analyses the structure of multiplex relations among stakeholders involved in the creation of a novel food waste management system, investigating the drivers of network formation when multiple collaborations are observed between pairs of stakeholders. We apply Social Network Analysis to study food waste reduction strategies in the City of Ferrara (Italy). Our results provide support for the practical relevance of multiple interactions across dyadic relationships in stakeholder networks. They also suggest that 'third parties' are not necessary for an effective networking strategy, and that relationships between stakeholders of similar levels of expertise are not required for establishing multiple relationships,

suggesting that functionally diverse coalitions are of greater practical relevance for food waste management strategies.

Keywords: food waste management; stakeholders; multiplexity; Social Network Analysis.

1. Introduction

Food waste is a global issue that is relevant for developed and developing countries alike, linking food safety, food security, and other key aspects of sustainability (FAO, 2019; Walia and Sanders, 2019). Urbanization and changing consumption habits have contributed to the rising food waste issue (Priefer et al., 2016). The third target of the United Nations Sustainable Development Goal 12 ('Ensure sustainable consumption and production patterns') commits countries to halve per-capita food waste at retail and consumption level, and to reduce food waste along the entire food chain by 2030. Recent estimates of food loss and waste generation range between 194-389 kg per person per year at the global scale, and between 158-298 kg per person per year at European level (Corrado and Sala, 2018), which translates into 88 million tons of food annually wasted, or equivalent losses of around 143 billion Euro (FUSIONS, 2016). Since the European Union (EU) is globally the second most significant contributor in terms of per capita food losses and waste at consumption and pre-consumption stages (FAO, 2019), it is unsurprising that debates on food waste management are thus becoming increasingly vocal amongst European stakeholders at national and local level (Gustavsson et al., 2011; Priefer et al., 2016; Grainger et al., 2018a).

The stakeholders interested in reducing food waste operate across the entire food supply chain, involving producers, food processors, retailers, consumers, social organizations, and public authorities (Lipinski et al. 2013; Halloran et al., 2014; Mourad, 2016; Aschemann-Witzel et al., 2017). There seems to be a consensus that reducing food waste requires a co-operative intervention among these stakeholders, to effectively introduce changes in technologies, practices, and policies that a single actor cannot afford (Papargyropoulou et al., 2014). Yet, we have limited insight into the nature of such co-operative intervention. Garcia-Garcia et al. (2017) suggest that handling complex food waste management systems requires a flexible relational analytical perspective. Previous work that has taken such a relational perspective in a food supply chain context suggests that stakeholders can achieve their objectives best through repeated interaction, and by relying on multiple relations, given the stakeholders' different interests, resources, and capabilities (Steiner et al., 2017). In the context of food waste management, previous work suggests that multi-stakeholder initiatives can foster the establishment of multiple overlapping relations, i.e. the exchange of information, the sharing of resources, and the development of cooperative projects (Kaipia et al., 2013; Lipinski et al. 2013; Mourad, 2016; Saint Ville et al., 2017).However, we observe a striking absence of studies that take into account multiplex networks in the context of food waste management systems. More specifically, it appears that no studies have thus far investigated the drivers of relationships in these networks, which are fundamental to understanding stakeholders' behaviour toward the implementation of novel food waste management systems. Empirical work as part of network studies has shown how specific endogenous network characteristics and exogenous organizational attributes drive the networking behaviour of stakeholders (Lazega et al., 2012; Lusher et al., 2013), but, to the best of our knowledge, this issue has not been explored in applied studies dedicated to food waste management.

Therefore, our study aims to fill this gap by exploring the drivers of stakeholder interactions in the creation of a novel food waste management system, contributing to the literature on food waste management in several ways. First, it demonstrates that a network perspective of multiplex relations is useful to understand how stakeholders define their structure of relationships. Second, our study highlights the role of relationship quality, by identifying three different formal and informal networking relationships in food waste management. Finally, we of augment the evidence base on food waste management case studies from different countries (Xu et al., 2016; Bustos and Moors, 2018), by adding the perspective of a representative European city particularly active on environmental issues. Our focus on the City of Ferrara (Italy) as a case study is motivated by its characteristics of being a representative mid-size European city that has taken national leadership by promoting a number of key initiatives aimed to support the circular economy perspective and to foster food waste reduction involving local stakeholders.

This paper is organized as follows. Section 2 describes relevant background to food waste management strategies in Europe, followed by a review of the relevant literature. Section 3 presents our hypotheses. Section 4 develops methods and data, while sections 5 and 6 present and discuss the results, respectively. Section 7 concludes, also providing policy implications and suggesting further research avenues.

2. Theoretical background

2.1 Food waste: definition and policymaking

The FAO Global Initiative on Food Loss and Waste Reduction defines food loss as a decrease in quantity or quality of food, intended as any substance suitable for human consumption (FAO, 2014: 4). The FAO (2011: 2) defines food waste as '*the food losses occurring at the end of the food chain*'; therefore, food waste can be seen as a subset of food loss consisting of edible food that has not been consumed by humans.

In order to minimize the amount of food waste, the European Commission invited EU Members to define a roadmap for reducing food waste, thus contributing to improve '*resource efficiency and food security at a global level*' (European Commission, 2011: 17).. In 2015, the Commission also adopted an Action Plan for the Circular Economy, including actions for stimulating food waste reduction (European Commission, 2015). However, national food waste policies in European countries are not homogeneous in their implementation. In Belgium, the Public Flemish Waste Management Company uses a food waste management hierarchy scheme that starts from prevention strategy, passes through the use as raw material in industry, and arrives at storage in landfills (De Clercq et al., 2017). The Spanish government has developed a waste strategy as part of the research project ‘More Food, Less Waste’, to collect data on food waste in households, industries, and farms, in order to implement a national strategy for reshaping the food chain (Blas et al., 2018). Germany devises strategies for supporting the circular economy, and a pivotal role is played by retailers, which are active in redistributing non-marketable food items to charitable organizations (Hermsdorf et al., 2017). Charitable organizations are particularly relevant also in Italy (Garrone et al., 2016), whose National Government implemented a national law in 2016 to regulate the distribution of edible food to reduce wastage[1].

2.2 Stakeholders and multiplex networks involved in food waste management

The food chain is a complex system characterized by a variety of relational risks (Priefer et al., 2016; Steiner et al., 2017), where the very nature of food (perishability) leads to potential food waste with corresponding environmental costs and dietary quality consequences (Conrad et al., 2018). As a result, knowledge transfer and cooperation between stakeholders can be an effective means to reduce negative externalities and transaction costs associated with relational risks (Buzby and Hyman, 2012; Lipinski et al., 2013).. Such collaborative initiatives are reflected in stakeholder relationships in terms of entrepreneurial ecosystems (Spigel, 2017); Figure 1 aims to visualize the key stakeholders that are involved in the food chain and in the planning of food waste management strategies (Figure 1).

[Figure 1]

[1] National Law n. 166, 19 August 2016: Provision regarding donation and distribution of food and pharmaceutical products for social solidarity and wastage reduction (16G00179) (‘*Disposizioni concernenti la donazione e la distribuzione di prodotti alimentari e farmaceutici a fini di solidarieta' sociale e per la limitazione degli sprechi (16G00179)’*).

Stakeholders' cooperation and the strengthening of inter-organizational relationships can lead to positive performance outcomes (Mena et al., 2011; Bliemel et al., 2016), though this depends on the types of stakeholder relationships (Uzzi, 1997; Rank et al., 2010). It is generally acknowledged that organizations are '*bound by manifold interdependencies within and across the layers of the network within which they are embedded*' (Simpson, 2015: 45). In the context of inter-organizational networks, network theory offers a perspective to simultaneously consider different interdependent layers (networks), therefore analysing the multiplex social structures underlying a relational context (Lomi and Pattison, 2006; Scott and Carrington, 2011). Multiplexity has increasingly become a key topic in organization and management studies because taking into account only single relations, rather than the whole set, can lead to biases in the analysis of network structures (Lomi and Pattison, 2006; Bliemel et al., 2016).

In the context of food waste management, the literature has further discussed the role of different relational forms in stakeholder networks. These forms can be identified as exchange of information, sharing of resources, and development of cooperative projects. Information exchange is considered an important source of organizational learning (Lazega et al., 2012); the more a stakeholder exchanges information with others, the more it will be stimulated to develop new ideas (Reed et al., 2014). The lack of information sharing between stakeholders is one of the main causes of food waste in the retail stores (Kaipia et al., 2013). Sharing resources (physical spaces and workforce) is also an important element in promoting the integration of a number of stakeholders in innovation activities (Fountain, 1998), especially in the food context (León-Bravo et al., 2017). In particular, the implementation of a novel food waste management system can be supported by the sharing of material resources, since the development of technologies and practices requires tools and people enabling this process (Lipinski et al. 2013). Finally, there is widespread evidence that formal cooperative projects are important for more effective sustainability-oriented organizations (Lozano, 2008; Govindan et al., 2016). Aschemann-Witzel et al. (2017) suggest that collaboration among stakeholders appears especially useful due to the complexity of the food waste issue. Garrone et al. (2016) provide evidence from ten Italian food manufacturers which highlight that the inclusion of non-governmental organizations (NGOs) in the decision-making process is not only supportive but necessary to reduce food waste effectively. Similarly, De Steur et al. (2016) and Mourad (2016) emphasize the importance of formal multi-stakeholder collaborations in the process of reducing food waste.

Furthermore, stakeholders may not limit their relations solely to the exchange of information in order to acquire knowledge which is not freely available: they can also decide to structure formal projects aimed at realizing innovative solutions (Mourad, 2016; Ribeiro et al. 2019). The conceptual perspective of multiplexity enables the analyst to consider the simultaneous existence of various forms of relationships, reflecting on the complexity and effectiveness of the underlying decision system among the stakeholders.

3. Hypotheses

Networks are characterized by the presence of two types of structures, which are the smallest elements of possible relational systems: dyads and triads. A dyad consists of a pair of actors and a link (tie) between them, which can be directed (e.g. an information sent from actor *i* to actor *j*) or undirected (e.g. a family relation between two individuals). Triads are made by three actors sharing a set of relationships; as for dyads, also triadic structures can present directed or undirected links. In multiplex networks, dyads and triads present multiple links at the same time that can be, as in the case of single networks, directed or undirected (Scott and Carrington, 2011).

At the dyadic level, the social embeddedness perspective suggests that when two actors form a link in a specific context, this behaviour is frequently related to the presence of other links (Shipilov and Li, 2012). The overall assumption is that those combinations of observed links are a reflection of stakeholders' perceived assets embedded in the food waste governance fabric (Reed et al., 2009;

Bodin and Prell, 2011). This mixed pattern of relationships between dyads can exist between the information exchange and the resource sharing relation, the information exchange and the projects-related relation, and the resource sharing and the projects-related relation: instrumental relationships based in the exchange of information are often observed in conjunction with more stable collaborations (sharing resources and collaborative projects), while sharing resources is fundamental to the success of a formal cooperative project, especially in the food chain (Galanakis, 2016). Considering the above observations, we propose the following competing hypotheses:

H1a) Considering dyads in food waste management networks, information exchange is observed in combination with resources sharing efforts of stakeholders;

H1b) Considering dyads in food waste management networks, information exchange exists in combination with relationships that are project-focused;

H1c) Considering dyads in food waste management networks, resource sharing exists in combination with project-focused relationships.

The presence of multiplex dyadic structures reflects the importance of establishing multiple collaborations between pairs of stakeholders. Besides, network scholars have also highlighted the importance of three-actor configurations, since dyadic relationships are not independent from their neighbourhood of relationships. Gulati and Gargiulo (1999) and Lomi and Pattison (2006) have pointed out that partners of the same actor are likely to become partners themselves as well, since shared partners are a source of trust and reliability. In closed network structures, trust can be a means for governance and can reduce the risk of opportunism (Williamson, 1993). The resulting closer and stronger relationships with lower costs of sanctioning are likely more effective as part of a bonding (social capital) relationship (Putnam, 2000). We assert that these benefits also carry over to triadic relationships among stakeholders involved in developing a new food waste management system, i.e. the benefits of triadic structures carry over to the exchange of information, the sharing of resources, and the development of cooperative projects. Simpson (2015: 44) suggests that '*tendencies for alliance to be embedded in triangles formed with co-occurring ties suggests that signalling, by means of structural position, helps to govern alliance formation in multilayered systems*'; moreover, as illustrated by Lee and Monge (2011), common third party ties between stakeholders in one network lead to the formation of a tie in another. Third parties are crucial in the food supply chain, because practices of food waste reduction are activated only when '*all parts of the food supply chain cooperate in mutual agreement*' (Priefer et al., 2016: 159). The above rationale leads us to propose the following hypotheses:

H2a) Considering triads in food waste management networks, the exchange of information between two stakeholders is observed in combination with resource sharing with third parties;

H2b) Considering triads in food waste management networks, the exchange of information between two stakeholders is observed in combination with projects-related links with third parties;

H2c) Considering triads in food waste management networks, the sharing of resources between two stakeholders is observed in combination with projects-related links with third parties.

In addition to the configuration of dyadic and triadic structures, organizational attributes also influence networking (Scott and Carrington, 2011). In particular, developing bridging network ties likely confer to the stakeholders in the food chain the benefits of open network structures (Blay-Palmer et al., 2016). Lavie (2006) has demonstrated that, from a Resource-Based View perspective, internal resources of the organization can be seen as generators of rents and quasi-rents. Yet, they can be drivers of inter-organizational alliances (Lomi and Pattison, 2006), as partners could search for interactions with different organizational structures in order to obtain inter-disciplinary skills and trans-organizational competencies (Boström et al., 2015; Thyberg and Tonjes, 2015). On the other hand, organizations recognize the benefits of endorsing relationships with partners possessing similar levels of expertise. In network theory, the concept of homophily defines a situation where two actors have a relation because of their similar characteristics, i.e. similar actors with respect to organizational attributes are more likely to establish relations with each other (Lazega et al., 2012). In the governance of a novel food waste management system, having similar levels of expertise facilitates interactions based on trust: because of the specificity of the topic, and the technical expertise that is required to manage such a sensitive issue, stakeholders prefer to rely on those who already show a deep knowledge of the food waste-related problems (Risvik and Finne, 2018). Hence, multiple relationships can more easily be developed on the basis of expertise similarities between stakeholders. Taking the above rationale into account, we propose the following hypothesis:

H3a) Considering food waste management networks, homophily between dyads (in terms of organization similarity) is negatively associated with the presence of multiplex ties across organizations;

H3b) Considering food waste management networks, homophily between dyads (in terms of expertise on food waste management) is positively associated with the presence of multiplex ties across organizations.

4. Data and methods

4.1. Empirical context: The City of Ferrara (Italy)

New strategies have been implemented in recent years in Europe (Vaqué, 2015), resulting in the development of multiple initiatives that have strengthened the cooperation between stakeholders at national, regional, and local level (Priefer et al., 2016). In Italy, the National Law n. 166/2016 led local and national stakeholders to develop new initiatives aimed to reduce food waste. Compared to other EU countries, Italy's food waste production per capita (179 Kg) is aligned with the EU average (173 Kg) (European Parliament, 2017). However, some Italian regions present high levels of food waste production (Piras et al., 2018); in particular, the Emilia-Romagna region shows one of the highest levels of household food waste, while this region has been a pioneer in food waste reduction initiatives by promoting, in 2015, a regional law for supporting circular economy and food waste reduction (Regione Emilia-Romagna, 2015). Therefore, this region provides a relevant and interesting case to investigate. Notably, we focus on the City of Ferrara, one of the nine main cities in Emilia-Romagna. Ferrara could be considered a representative mid-size European city (approximately 130,000 inhabitants in 2018), which has implemented a number of circular economy-related practices and initiatives during the past years (Bonato and Orsini, 2018; Municipality of Ferrara, 2014). Moreover, it has been among the first Italian cities to support the creation of a multi-stakeholder network aimed to promote circular economy and food waste reduction in the community (Municipality of Ferrara, 2014).

Primary data for this paper were collected using a questionnaire applied to the stakeholders mapped for the EU Interreg Project 'ECOWASTE4FOOD' (2017-2020), dedicated to the improvement of policy tools for promoting circular economy and food waste reduction. In collaboration with the Centre for Sustainability Education (CEAS) of the City of Ferrara, we created an initial list of key local stakeholders (organizations) that were involved in circular economy or food waste reduction initiatives, or whose mission presented a connection with these topics. Afterwards, a Snowball Sampling Approach (Scott and Carrington, 2011) was used to identify other stakeholders, considering the importance of organizational characteristics and local representativeness of the different groups (Friedman and Miles, 2006). In total, 42 local stakeholders were mapped out: farmers, retailers, public authorities, research centres, consumer associations, and NGOs. During the first phase of this project, the representatives of these stakeholders were invited to participate in four round tables and one international workshop between November 2017 and April 2018, for discussing about strengths and weaknesses of the food chain, since public participation is considered a key element in food waste management (Refsgaard and Magnussen, 2009; Priefer et al., 2016). Those representatives, which were in charge of providing information about their organizations, were mainly managers, project coordinators, high-level researchers and professors, and presidents of the organizations; thus, individuals with relevant expertise and awareness of the activities and the strategies of their organizations. We submitted the questionnaire during these events; we also created an online version for those who were not available during the round tables but still interested in completing the survey. The final version of the questionnaire is presented in Appendix 1: since the original version is in Italian, the text has been translated into English. Network data were collected using a roster recall method (Scott and Carrington, 2011): a complete list (roster) of all the 42 stakeholders has been included in the questionnaire, including the possibility to indicate a maximum of five additional stakeholders not listed in the roster, and respondents could specify the existence of a given type of relationship their organization activated in the last five years. With regard to the stakeholder attributes, we asked for general information on the organization (e.g., type of organization) and the level of expertise (of the organization, not the individual respondent) in food waste management activities, using a five-point Likert scale ranging from ‘Not at all’ to ‘Excellent’.

4.2. Method: bivariate Exponential Random Graph Models (ERGMs)

Since we aim to detect drivers of inter-organizational networking, we adopt a quantitative method approach based on Social Network Analysis (SNA). SNA is used to visualize and analyse network data: the relational structures are depicted through graphs, were actors (individuals, organizations, or other entities) are represented as nodes and relations as lines (Scott and Carrington, 2011). The actors operating in a specific network can be characterized by a variety of relationships, and their behaviour can be driven by endogenous network forces and actor-level attributes. In this study, we use bivariate Exponential Random Graph Models (ERGMs) for investigating network structures, which are probability models for complete networks that allow to estimate the effect of network structures (dyads and triads) and actors' attributes on network formation, when two networks are observed simultaneously (Snijders et al., 2006; Robins et al., 2007; Simpson, 2015). These models make it possible to consider the interdependence of multiplex network structures made by two networks when making inference on how relationships are created.

Univariate ERGMs, i.e. models that consider one network at a time, take the following form (Robins et al. 2007):

$$Pr(Y = y) = (\frac{1}{k}) exp\{\sum_A \eta_A Z_A(y)\} \quad (1)$$

The probability that the observed network *y* is identical to the randomly generated network *Y* is given by an exponential model, where ηA is the parameter corresponding to network configuration *A* and $Z_A(y)$ is the network statistic corresponding to configuration *A*. Assuming that all counted network formation instances are equiprobable, Markov dependence allows to identify the associated parameters for each configuration. For the bivariate ERGMs, $Z_A(y)$ is a bi-graph defined by the relationships across the two networks under examination[2].

In this study, three different bivariate ERGMS are estimated: information exchange and resource sharing; information exchange and cooperative projects; resource sharing and cooperative projects. Since the relationships in these networks are undirected, only specific parameters for undirected networks have been included in the models (Table 1). We named the information exchange network as network A, the resource sharing network as network B, and the cooperative projects network as network C. *Edge* parameters (*EdgeA*, *EdgeB*, and *EdgeC*) control for the number of edges in the network. *EdgeAB*, *EdgeAC*, and *EdgeBC* are used to test for the co-occurrence, at dyadic level, of

[2] For a detailed description of univariate and bivariate ERGMs estimation and simulation, see Koskinen and Snijders (2013) and Wang (2013).

two types of relationships in bivariate networks, i.e. testing hypotheses 1a-1c. Triadic configurations *TriangleAAB*, *TriangleAAC*, *TriangleBBC*, *TriangleABB*, *TriangleACC*, *TriangleBCC*, *AT-ABA*, *AT-ACA*, *AT-BCB*, *AT-CAC*, *AT-CBC*, and *AT-BAB* are used to test hypotheses 2a-2c. The *Triangle* configurations represent collaborations between pairs of organizations having a common contact with whom they have established another type of relation; the alternating triangles (*AT*) configurations control for the 'social circuit effect' (Lusher et al., 2013), i.e. the presence of cohesive subsets of triangles in denser parts of the network, where edges combine different forms of collaborations. Hypothesis 3a is tested using *MatchAB_cat*, *MatchAC_cat*, and *MatchBC_cat*, while *MatchAB_exp*, *MatchAC_exp*, and *MatchBC_exp* test for the presence of homophily, in terms of expertise level, as a driver of networking between stakeholders (hypothesis 3b). Stakeholders' expertise has been coded as a dummy equal to one when respondents identify their organization having 'good' or 'excellent' competences (points four and five of the Likert scale, respectively) on food waste management, zero otherwise. Organization similarity is detected when two organizations belong to the same stakeholder category (consumer association, NGO, private enterprise, public authority, research centre).

In the estimation process, the convergence t-ratio (estimate divided by standard error) for each parameter should be less than or close to 0.1 in absolute value. Estimates that are more than twice their standard errors are considered statistically significant (Robins et al., 2007), and a positive and significant estimate indicates that there is a structural effect which can not be explained by a random set of ties in the network.

[Table 1]

Once the estimates are obtained, goodness-of-fit (GOF) tests are conducted following the procedures suggested by Hunter et al. (2008). A sample of 1,000 simulated networks is compared with the observed network, with respect to the differences between their characteristics. As well as for the estimation process, in GOF tests the t-ratio for each network statistic must be less than 0.1 in absolute value. XPnet software (Wang et al., 2009) is used for the analysis. Results of the GOF are illustrated in Appendix 2.

5. Results

We received 22 questionnaires out of 42 sent, obtaining a 51% response rate: ten public authorities (of which one research centre), seven NGOs, and five private enterprises (of which two of the major regional retailers and one of the main Italian food producers). The 22 stakeholders show 58 dyadic relations with respect to the exchange of information, 39 dyadic relations based on the sharing of resources, and 62 dyadic relations illustrative of cooperative projects (Figures 2-4; square nodes are public authorities, circle nodes are NGOs, and triangle nodes are private enterprises).

[Figure 2]

[Figure 3]

[Figure 4]

Table 2 reports the results for the three bivariate ERGMs. The *EdgeAB*, *EdgeAC*, and *EdgeBC* parameters are positive and significant in all three networks, i.e. the co-occurrence of multiple collaborations between pairs of stakeholders is consistent with hypotheses H1a-H1c. As a matter of fact, the establishment of a type of collaboration between two stakeholders increases the probability that the same actors establish another type of collaboration. This result suggests that attitudes of two stakeholders, who are both involved in the food waste management system, are such that they prefer to develop relationships of different kinds, while strengthening their mutual reliance. On the other hand, triadic multiplex configurations are almost never statistically significant. In particular, for the first (‘Information exchange (A) & Resource sharing (B)’) and the third (‘Resource sharing (B) & Cooperative projects (C)’) bivariate networks, none of the triadic configurations is statistically significant. This indicates that sharing resources between stakeholders does not favour the formation of triadic relationships supporting other types of collaboration; the assumption that sharing a food waste related network relationship with the same third party (for instance, stakeholders *i* and *j* exchanging information with the same stakeholder *z*) would encourage the creation of a new relationship in another network (e.g. a cooperative project) is not confirmed. We also observe that having a connection with the same stakeholder in a network is not considered enough by network members to engage in a new food waste management-oriented relationship; in this sense, it seems that trust and confidence are not transitive toward new relationships. Only for the second bivariate network ('Information exchange (A) & Cooperative projects (C)') the *AT-ACA* configuration is positive and statistically significant. This suggests that stakeholders who have a dense exchange of information with the same third parties have a high propensity to interact with their partner for developing formal collaborations, providing limited support for the presence of bridging social capital (Putnam, 2000). Given this mixed evidence, we reject Hypotheses 2a-2c.

[Table 2]

Hypotheses 3a-3b, which examine homophily in multiplex relations with respect to stakeholders' organizational structure and expertise in food waste management, cannot be supported by the bivariate ERGMs results. On one hand, belonging to the same organizational category (*MatchAB_cat*, *MatchAC_cat*, and *MatchBC_cat*) decreases the probability to establish multiple networks: the parameter coefficients are all negative, and in one case (*MatchAB_cat*, for the multiplex network 'Information exchange (A) & Resource sharing (B)') we observe a statistically significant result. However, this is not sufficient to confirm hypothesis 3a. On the other hand, *MatchAB_exp*, *MatchAC_exp*, and *MatchBC_exp* present a positive sign, suggesting that stakeholders with a similar level of expertise are likely to establish multiple relationships, mostly to support information exchange and collaborative projects; however, none of the above parameters is statistically significant, and hence we cannot confirm hypothesis 3b.

6. Discussion

One way to address food waste reduction is through effective waste management strategies. In the context of food waste management systems that connect relevant stakeholders, the relational drivers influencing stakeholders' networking are the basis for understanding stakeholders' behaviour toward the implementation of novel systems for waste reduction. Ferrara is characterized by the presence of informal (information exchange) and formal (resource sharing and cooperative projects) relationships between a set of actors with different organizational forms and expertise. The results of our study suggest that there is a positive chance for two organizations (dyadic level) to establish multiple relationships aimed to develop a new food waste management system. According to the social embeddedness perspective (Shipilov and Li, 2012), those actors who have already established relationships in specific contexts are more likely to trust in their partners and develop multiple relationships among each other. However, multiplexity is not detected in triadic structures: relying on 'third parties' to expand the network of multiplex relationships does not play a role in supporting the networking process between stakeholders acting in the food waste management system under investigation. This result indicates that stakeholders who are looking at new networking opportunities are less likely to trust in actors other than their current partners. They seem to perceive that the benefits in terms of multiple sources of information or resources obtained by relating to more than a single partner do not outweigh the costs in terms of the dark side of trust due to over-embeddedness in existing relationships (Uzzi, 1997; Hagedoorn and Frankort, 2008). In this sense, our results suggest that social embeddedness could also lead to lock-in problems (Dosi and Malerba, 1996). In other words, the innovative process of creating a novel food waste management system seems to be grounded on basic (dyadic) networking relationships, where the lack of shared trust, which prevents stakeholders from the development of triadic network structures, is not compensated by perceived benefits of one-to-one agreements based on information exchange, resource sharing, and the creation of formal projects. A positive, but not statistically significant, effect on the establishment of multiple collaborations between stakeholders is produced by the presence of homophily in terms of similar levels of expertise on food waste management. Hence, the level of expertise does not seem to be a strong driver of multiplex networking. This result could be due to the dimension of the system under investigation: local stakeholders know their strengths and weaknesses, and relying exclusively on the level of expertise to establish a relation is sometimes detrimental for trust between actors (Newman and Dale, 2007). On the other hand, belonging to the same organizational category is negatively associated with the presence of multiplexity when considering the 'Information exchange' and the 'Resources sharing' networks, advocating that local stakeholders in Ferrara do not have a strong interest in multiple collaborations with stakeholder organizations of a similar nature, at least for the above types of relationships. This result suggests that existing relationships have already achieved the level of partnership-internal resource requirements (Harrison et al., 2001; Lin et al., 2009) that motivated the establishment of the partnership in the first place and that the imperfect tradability of resources that motivates the formation of alliances and collaborations (Das and Teng, 2000; Steiner et al., 2017), as put forward by the Resource-Based View (Barney, 2001; Lavie, 2006), is not motivating stakeholders to go beyond their existing relationships. The perceived low costs of over-embeddedness (Hagedoorn and Frankort, 2008) associated with existing relationships and the potentially high transaction costs of establishing further relationships (Williamson 1993) seem to outweigh the perceived benefits from establishing novel relationships, and it is perhaps due to this combination of factors that there is no interest for establishing other types of relationships with similar stakeholders.

7. Conclusions

Food waste is a global issue that could be tackled through co-operative efforts amongst food chain stakeholders. Since European countries are among the most significant contributors in terms of per capita food waste in the world (FAO, 2019), different mixed top-down/bottom up approaches are being adopted in these countries to address this problem. In order to be effective, previous evidence suggests that food waste policies should be developed according to evidence-based data (Grainger et al., 2018b). Our paper employs evidence from an archetypal Italian and thus European municipality, investigating the relative effectiveness of drivers of network formation through the analysis of organizational attributes of its food waste management system. Our results suggest that a more integrated network of multiplex relationships between stakeholders involved in food waste management strategies is needed for establishing an effective stakeholder network tasked with reducing food waste. Our analysis explores three sets of hypotheses involving, on one hand, the dyadic and the triadic relationships among stakeholders, and on the other hand, the degree of homophily that is identified as desirable and effective by the stakeholders when putting into practice food waste management stakeholder networks.

To the best of our knowledge, this paper is the first attempt investigating the multiplex networks intervening in the implementation of a novel food waste management system. Focusing on the drivers of networking between stakeholders, we find that an existing relationship between two stakeholders is positively and robustly related to the propensity to establish novel relationships of different types. Hence, members of the food waste eco-system in Ferrara are found to be more willing to collaborate with well-known organizations, rather than with novel partners in different networks. However, when considering more complex structures as drivers of networking (i.e. triadic relational structures), there is no evidence of their influence on stakeholders' networking behaviour. Furthermore, the analysis suggests that homophily in food waste stakeholder networks is not a driver of multiplex relations that could support an effective reduction of food waste: stakeholders with a different organizational form than their own tend to avoid multiple relationships with others, while there is not statistical evidence of a more pro-active behaviour by those stakeholders with a similar level of expertise on food waste issues. Our empirical evidence thus contrasts with previous work suggesting that for stakeholder relationships to effectively handle food waste management issues, organizations are required to differ in terms of knowledge gained through access to different stakeholders (with regard to personal history, mission and objectives), thereby benefiting from bridging social capital (Putnam, 2000; Burt, 2005).

Therefore, our findings are particularly significant to the extent that they suggest that the food waste networking system under investigation promotes bonding (i.e. the strengthening of relationships between close members), rather than bridging (i.e. the linking of new partners) social capital. Additionally, one could conjecture that the dark side of trust, in terms of costs of over-embeddedness (Hagedoorn and Frankort, 2008) in the network under investigation, is not perceived as sufficiently relevant by the stakeholders in question, to motivate them toward bridging beyond their existing relationship partners.

Our results suggest a number of policy implications, which relate to the likelihood of food waste network stakeholders toward strengthening their relationships through the participation in different networks. First, our results corroborate with Niesten et al. (2017), suggesting that more policy (institutional) support is needed for more collaboration of boundary-spanning organizational networks. In particular, local authorities could provide institutional and financial incentives for strengthening knowledge transfer and spurring cooperative projects to more effectively deal with food waste issues. Practical policy tools could also include the encouragement of stakeholder participation in mixed working groups aimed at developing functionally diverse food waste management coalitions for more effective food waste management strategies. At the same time, it is necessary to support these coalitions towards common planning, for example by enabling them to influence the institutional framework for local food waste management, or by supporting them with seed-funding and resources to acquire external funding at national and European level. These resources could thus be used for a more extensive stakeholder-weaving (Vance-Borland and Holley, 2011) and the support of further bridging networking activities, for example by targeting central communication stakeholders to identify effective leverage points for more boundary-spanning food waste management efforts.

The main limitation of our analysis lies in the cross-sectional nature of our case study. Areas for future research involve a comparison of multiple regions, and the collection of longitudinal network data. This could help to identify the impact of institutional differences on the effectiveness of relational characteristics among stakeholders in dealing with food waste management issues.

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Figure 1. Stakeholders involved in the food waste management system.

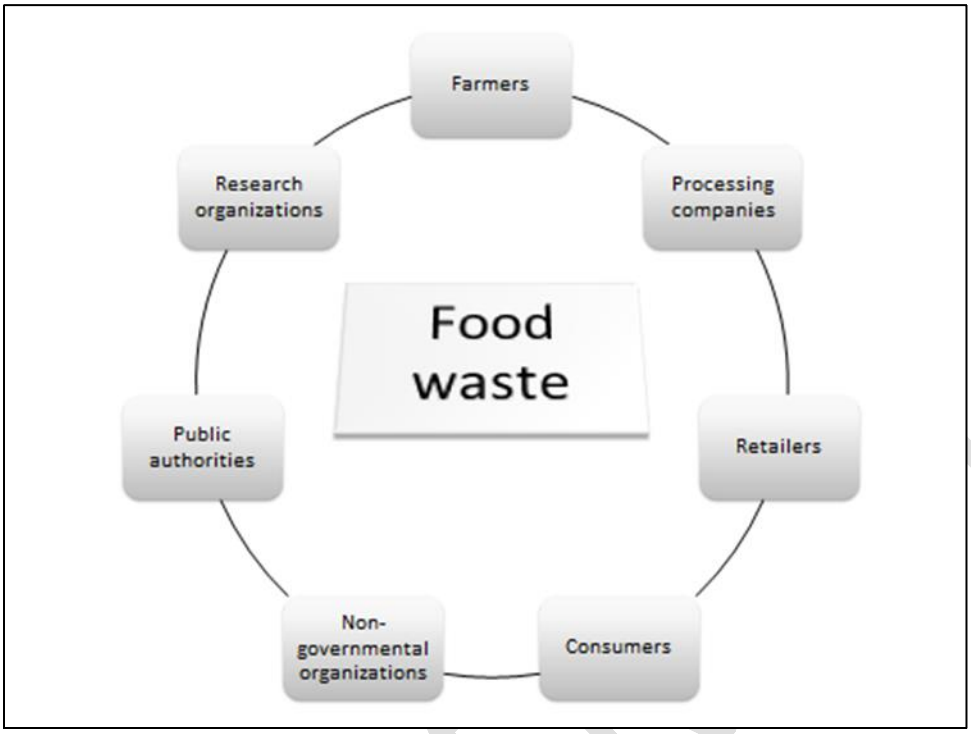
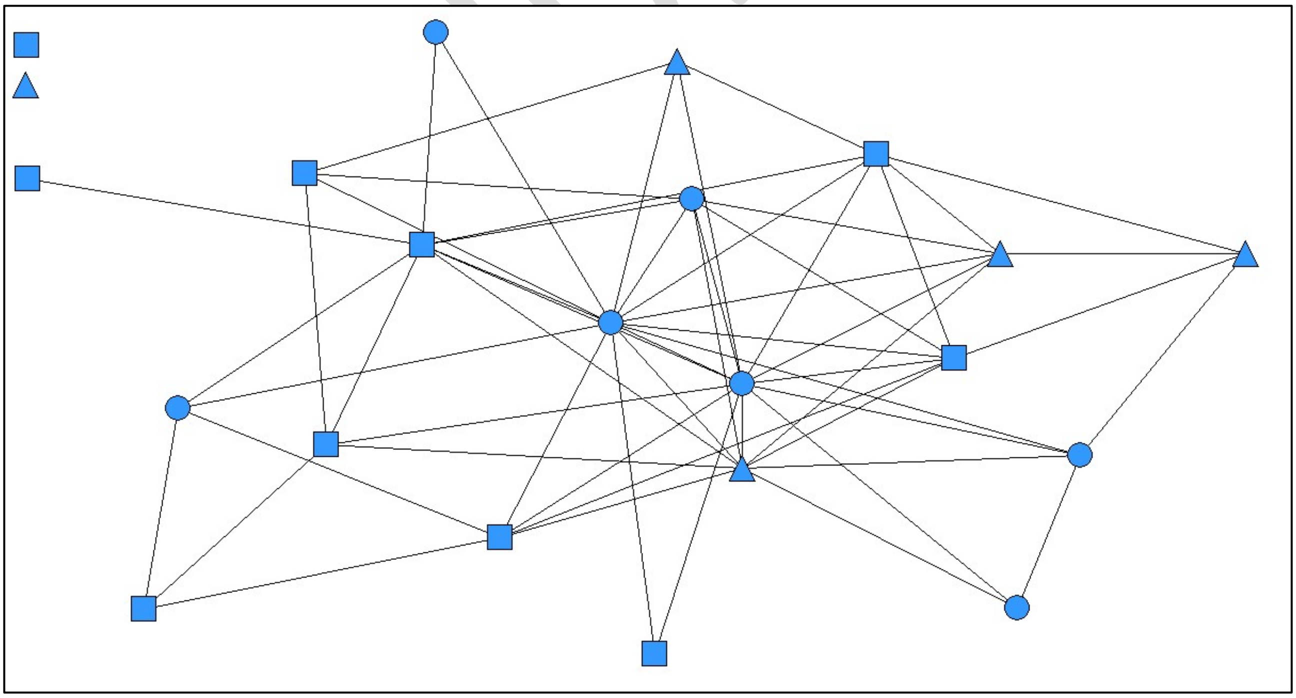
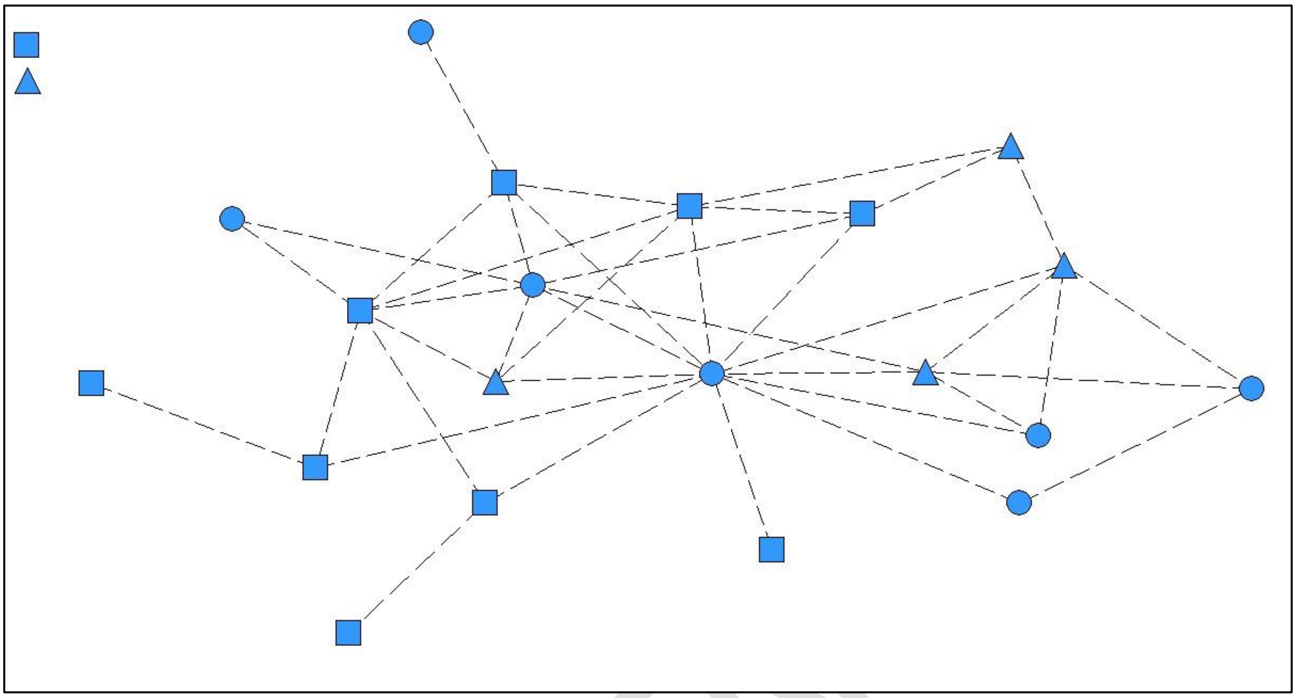


Figure 2. Information exchange network.



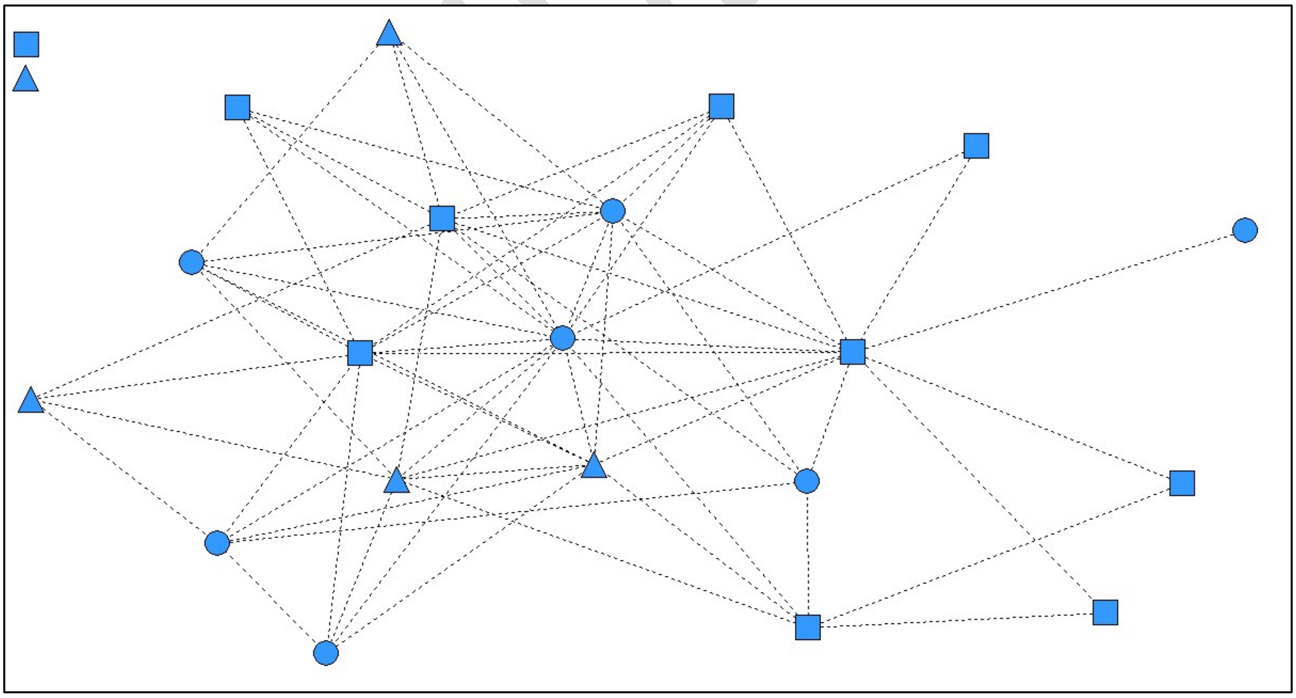
Legend: square nodes are public authorities; circle nodes are NGOs; triangle nodes are private enterprises.

Figure 3. Resource sharing network.



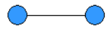
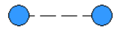
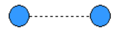
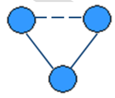
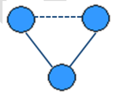
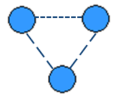
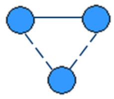
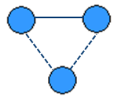
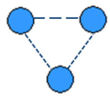
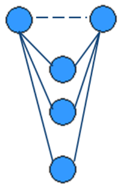
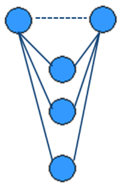
Legend: square nodes are public authorities; circle nodes are NGOs; triangle nodes are private enterprises.

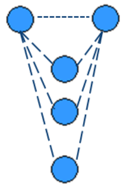
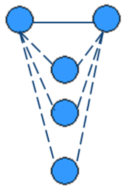
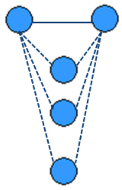
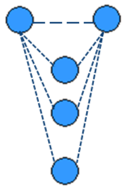
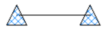
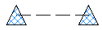
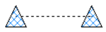
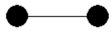
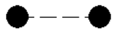
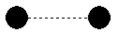
Figure 4. Cooperative projects network.



Legend: square nodes are public authorities; circle nodes are NGOs; triangle nodes are private enterprises.

Table 1. Bivariate ERGMs configurations.

Configuration	Hypothesis tested	Visualization
EdgeA		
EdgeB		
EdgeC		
EdgeAB	H1a	
EdgeAC	H1b	
EdgeBC	H1c	
TriangleAAB	H2a	
TriangleAAC	H2b	
TriangleBBC	H2c	
TriangleABB	H2a	
TriangleACC	H2b	
TriangleBCC	H2c	
AT-ABA	H2a	
AT-ACA	H2b	

AT-BCB	H2c	
AT-BAB	H2a	
AT-CAC	H2b	
AT-CBC	H2c	
MatchA_cat		
MatchB_cat		
MatchC_cat		
MatchA_exp		
MatchB_exp		
MatchC_exp		
MatchAB_cat	H3a	
MatchAC_cat	H3a	
MatchBC_cat	H3a	
MatchAB_exp	H3b	
MatchAC_exp	H3b	
MatchBC_exp	H3b	

Legend: Information exchange relationship = solid line; resource sharing relationship = dash line; cooperative projects relationship = square dot line.

Table 2. Bivariate ERGMs estimates.

	Information exchange (A) & Resource sharing (B)		Information exchange (A) & Cooperative projects (C)		Resource sharing (B) & Cooperative projects (C)	
	Estimate (SE)	t-ratio	Estimate (SE)	t-ratio	Estimate (SE)	t-ratio
EdgeA	**-2.956 (0.388)***	**0.012**	**-3.732 (0.515)***	**-0.017**		
EdgeB	**-4.904 (0.789)***	**0.066**			**-4.706 (0.753)***	**0.076**
EdgeC			**-3.648 (0.491)***	**-0.016**	**-2.896 (0.381)***	**0.074**
EdgeAB	**3.995 (0.835)***	**0.048**				
EdgeAC			**2.391 (0.539)***	**-0.015**		
EdgeBC					**3.223 (0.694)***	**0.077**
TriangleAAB	0.160 (0.120)	-0.005				
TriangleAAC			0.008 (0.125)	-0.050		
TriangleBBC					-0.205 (0.206)	0.060
TriangleABB	-0.270 (0.239)	0.011				
TriangleACC			0.017 (0.113)	-0.048		
TriangleBCC					0.176 (0.126)	0.062
AT-ABA	0.175 (0.435)	0.036				
AT-ACA			**0.935 (0.456)***	**-0.032**		
AT-BCB					0.457 (0.472)	0.069
AT-BAB	0.860 (0.494)	0.020				
AT-CAC			0.487 (0.463)	-0.029		
AT-CBC					0.681 (0.541)	0.067
MatchA_cat	0.559 (0.475)	-0.002	0.677 (0.576)	-0.028		
MatchB_cat	**2.280 (0.878)***	**0.086**			1.416 (0.846)	0.075
MatchC_cat			0.816 (0.516)	-0.037	0.383 (0.440)	0.085
MatchA_exp	0.503	0.014	-0.624	0.019		

	(0.466)		(0.704)			
MatchB_exp	-0.408 (0.887)	0.041			-1.038 (1.171)	0.091
MatchC_exp			-0.310 (0.595)	0.025	0.535 (0.414)	0.068
MatchAB_cat	**-2.461 (1.033)***	**0.044**				
MatchAC_cat			-1.097 (0.834)	-0.019		
MatchBC_cat					-1.198 (1.017)	0.073
MatchAB_exp	0.367 (1.000)	0.026				
MatchAC_exp			1.569 (0.922)	0.027		
MatchBC_exp					0.961 (1.274)	0.093

* = Significant parameter, in bold.

Appendix 1: Questionnaire

This Appendix illustrates the structure of the questionnaire that has been used for the data collection in the City of Ferrara as part of the EU Interreg Project 'ECOWASTE4FOOD'. Section 3 (COLLABORATIONS) present a different version of the roster which has been used to collect network data: because of privacy constraints, it is not possible to show the full name list of stakeholders that have been identified in the research. Therefore, we have anonymized the roster, using ID numbers instead of real names of the organizations.

1) GENERAL INFORMATION

a) Organization: ____

b) Categoria di appartenenza:

❒Non profit organization

❒Foundation

❒Public authority

❒Private enterprise

❒School

Others____

c) Number of employees ____

d) First and family name of the respondent: ____

e) Role in the organization: ____

2) ACTIVITIES

In the following table, please indicate the level of commitment of your organization in the development of the following activities related to the Circular Economy:

	No commitment	Low	Medium	High
Management ecosystem services	❒	❒	❒	❒
Challenge food waste	❒	❒	❒	❒
Short supply chain experiences	❒	❒	❒	❒
Water and energy saving initiatives	❒	❒	❒	❒
Waste management initiatives	❒	❒	❒	❒

How do you judge the performance of your organization in the development of the following activities related to the Circular Economy?

	Not at all	Poor	Sufficient	Good	Excellent
Management ecosystem services	❒	❒	❒	❒	❒
Challenge food waste	❒	❒	❒	❒	❒
Short supply chain experiences	❒	❒	❒	❒	❒
Water and energy saving initiatives	❒	❒	❒	❒	❒
Waste management initiatives	❒	❒	❒	❒	❒

3) COLLABORATIONS

In the following table are listed the local organizations operating in activities aimed to reduce food waste. Please indicate with which organizations your organization has established relationships in the last five years, specifying the type of relationship (Information exchange; Resource sharing; Creation of cooperative projects). It is possible to indicate multiple relationships with the same organization. The three types of relationships are defined as:

- Information exchange: information regarding events, fairs, new technologies or innovation related to food waste reduction;
- Resource sharing: sharing of spaces or human resources.

- Creation of cooperative projects: formal agreements (contractualized) aimed to the development of specific projects.

You can add other organizations, not presented in the list, with which your organization had one or more relationships in the last five years by filling the last rows of the matrix. You can add a maximum of five additional organizations.

Organization	Specify organization (for “Other” answers)	Type of relationship established in the last 5 years. It is possible to indicate multiple relationships with the same organization.		
		Information exchange	Resource sharing	Creation of cooperative projects
ID1		❒	❒	❒
ID2		❒	❒	❒
ID3		❒	❒	❒
ID4		❒	❒	❒
ID5		❒	❒	❒
ID6		❒	❒	❒
ID7		❒	❒	❒
ID8		❒	❒	❒
ID9		❒	❒	❒
ID10		❒	❒	❒
ID11		❒	❒	❒
ID12		❒	❒	❒
ID13		❒	❒	❒
ID14		❒	❒	❒
ID15		❒	❒	❒
ID16		❒	❒	❒
ID17		❒	❒	❒

ID18		❒	❒	❒
ID19		❒	❒	❒
ID20		❒	❒	❒
ID21		❒	❒	❒
ID22		❒	❒	❒
ID23		❒	❒	❒
ID24		❒	❒	❒
ID25		❒	❒	❒
ID26		❒	❒	❒
ID27		❒	❒	❒
ID28		❒	❒	❒
ID29		❒	❒	❒
ID30		❒	❒	❒
ID31		❒	❒	❒
ID32		❒	❒	❒
ID33		❒	❒	❒
ID34		❒	❒	❒
ID35		❒	❒	❒
ID36		❒	❒	❒

ID37		❒	❒	❒
ID38		❒	❒	❒
ID39		❒	❒	❒
ID40		❒	❒	❒
ID41		❒	❒	❒
ID42		❒	❒	❒
Other (specify):	______________	❒	❒	❒
Other (specify):	______________	❒	❒	❒
Other (specify):	______________	❒	❒	❒
Other (specify):	______________	❒	❒	❒
Other (specify):	______________	❒	❒	❒

Appendix 2: Goodness-of-fit results

Goodness-of-fit results for the bivariate network ‘Information exchange (A) & Resource sharing (B)’.

Statistic	Observed	Mean	Std. Dev.	t-ratio
EdgeA	58	60.412	18.808	-0.128
2-StarA	395	397.44	219.326	-0.011
3-StarA	1037	946.318	719.237	0.126
TriangleA	56	58.135	40.338	-0.053
AAS-A(2.00)	158.481	165.28	68.52	-0.099
AKTA(2.00)	85.854	86.342	43.952	-0.011
A2PA(2.00)	236.197	228.734	87.33	0.085
T3uAA-expertise	21	22.296	16.283	-0.08
T2uA-expertise	93	90.872	62.916	0.034
T1uA-expertise	128	125.077	85.358	0.034
O3uA-expertise	121	122.794	68.41	-0.026
O2auA-expertise	388	378.863	204.003	0.045
O2buA-expertise	178	164.275	88.089	0.156
O1auA-expertise	307	287.075	155.181	0.128
O1buA-expertise	532	515.976	276.878	0.058
RbA-expertise	26	26.473	8.33	-0.057
RA-expertise	80	78.885	23.958	0.047
Matching A-cat	19	19.682	6.016	-0.113
Mismatching A-cat	39	40.73	14.031	-0.123
EdgeB	39	40.464	13.239	-0.111
2-StarB	182	183.48	98.902	-0.015
3-StarB	353	302.328	216.935	0.234
TriangleB	18	19.462	11.91	-0.123
AAS-B(2.00)	89.501	94.713	42.403	-0.123
AKTB(2.00)	39.375	42.467	22.702	-0.136
A2PB(2.00)	142.156	141.403	66.109	0.011
T3uAB-expertise	6	6.945	5.052	-0.187
T2uB-expertise	26	28.664	18.384	-0.145
T1uB-expertise	38	40.474	24.566	-0.101
O3uB-expertise	53	54.168	31.795	-0.037
O2auB-expertise	166	167.761	92.175	-0.019
O2buB-expertise	74	73.852	38.896	0.004
O1auB-expertise	136	128.334	69.565	0.11
O1buB-expertise	229	234.578	122.761	-0.045
RbB-expertise	17	17.274	6.114	-0.045
RB-expertise	52	51.943	16.944	0.003
Matching B-cat	15	15.568	4.812	-0.118
Mismatching B-cat	24	24.896	9.718	-0.092
EdgeAB	32	33.436	12.666	-0.113
2-Star-AB	530	543.191	293.244	-0.045
3-Star-AAB	2071	1955.285	1433.951	0.081
3-Star-ABB	1424	1335.24	957.223	0.093

Triangle-AAB	114	124.168	80.337	-0.127
Triangle-ABB	80	86.605	53.225	-0.124
Isolate-AB	2	0.663	0.94	1.422
AKTABA(2.00)	57.01	60.723	29.045	-0.128
AKTBAB(2.00)	58.563	62.873	33.781	-0.128
mr-expertise	15	15.312	6.037	-0.052
mb-expertise	46	44.831	16.542	0.071
Matching EdgeAB-cat	10	10.452	4.325	-0.105
Mismatching EdgeAB-cat	22	22.984	9.476	-0.104
Std Dev degree distA	3.658	2.862	0.591	1.347
Skew degree distA	0.768	0.235	0.404	1.319
Global ClusteringA	0.425	0.398	0.093	0.292
Mean Local ClusteringA	0.468	0.381	0.117	0.743
Variance Local ClusteringA	0.083	0.061	0.027	0.809
Std Dev degree distB	2.742	2.274	0.457	1.024
Skew degree distB	1.207	0.481	0.465	1.56
Global ClusteringB	0.297	0.302	0.066	-0.074
Mean Local ClusteringB	0.284	0.289	0.099	-0.047
Variance Local ClusteringB	0.098	0.077	0.035	0.597

Goodness-of-fit results for the bivariate network ‘Information exchange (A) & Cooperative projects (C)’.

Statistic	Observed	Mean	Std. Dev.	t-ratio
EdgeA	58.000	65.101	15.752	-0.451
2-StarA	395.000	451.242	165.012	-0.341
3-StarA	1037.000	1096.530	511.815	-0.116
TriangleA	56.000	65.933	26.122	-0.380
AAS-A(2.00)	158.481	183.659	54.954	-0.458
AKTA(2.00)	85.854	101.261	32.465	-0.475
A2PA(2.00)	236.197	258.324	75.042	-0.295
T3uAA-expertise	21.000	24.763	11.423	-0.329
T2uA-expertise	93.000	101.555	41.305	-0.207
T1uA-expertise	128.000	140.776	54.396	-0.235
O3uA-expertise	121.000	134.620	52.266	-0.261
O2auA-expertise	388.000	422.343	152.104	-0.226
O2buA-expertise	178.000	182.052	63.337	-0.064
O1auA-expertise	307.000	324.964	116.232	-0.155
O1buA-expertise	532.000	579.083	201.068	-0.234
RbA-expertise	26.000	28.025	6.836	-0.296
RA-expertise	80.000	84.608	19.364	-0.238
Matching A-cat	19.000	21.055	5.261	-0.391
Mismatching A-cat	39.000	44.046	12.022	-0.420
EdgeC	62.000	69.589	17.224	-0.441
2-StarC	443.000	513.448	194.561	-0.362
3-StarC	1150.000	1315.252	639.876	-0.258
TriangleC	65.000	79.053	33.249	-0.423
AAS-C(2.00)	174.353	200.800	61.203	-0.432
AKTC(2.00)	92.961	111.642	36.728	-0.509
A2PC(2.00)	249.680	272.421	78.452	-0.290
T3uAC-expertise	20.000	30.252	14.455	-0.709
T2uC-expertise	93.000	123.181	52.930	-0.570
T1uC-expertise	137.000	169.670	69.814	-0.468
O3uC-expertise	127.000	155.512	61.493	-0.464
O2auC-expertise	400.000	484.363	179.904	-0.469
O2buC-expertise	181.000	209.121	75.287	-0.374
O1auC-expertise	307.000	369.701	136.565	-0.459
O1buC-expertise	576.000	662.355	239.161	-0.361
RbC-expertise	28.000	30.216	7.411	-0.299
RC-expertise	83.000	90.643	21.142	-0.362
Matching C-cat	21.000	23.493	5.940	-0.420
Mismatching C-cat	41.000	46.096	12.651	-0.403
EdgeAC	43.000	48.595	13.161	-0.425
2-Star-AC	836.000	969.635	355.111	-0.376
3-Star-AAC	3137.000	3523.811	1629.555	-0.237
3-Star-ACC	3271.000	3745.912	1759.468	-0.270
Triangle-AAC	187.000	215.708	83.763	-0.343
Triangle-ACC	198.000	228.533	90.944	-0.336

Isolate-AC	2.000	0.655	0.985	1.365
AKTACA(2.00)	95.916	110.413	35.000	-0.414
AKTCAC(2.00)	92.680	106.651	33.219	-0.421
mr-expertise	23.000	24.786	6.522	-0.274
mb-expertise	64.000	68.365	17.291	-0.252
Matching EdgeAC-cat	14.000	15.708	4.553	-0.375
Mismatching EdgeAC-cat	29.000	32.887	10.084	-0.385
Std Dev degree distA	3.658	3.117	0.389	1.390
Skew degree distA	0.768	0.256	0.440	1.164
Global ClusteringA	0.425	0.434	0.043	-0.195
Mean Local ClusteringA	0.468	0.436	0.079	0.409
Variance Local ClusteringA	0.083	0.062	0.032	0.646
Std Dev degree distC	3.760	3.220	0.404	1.338
Skew degree distC	0.412	0.133	0.417	0.670
Global ClusteringC	0.440	0.453	0.049	-0.271
Mean Local ClusteringC	0.424	0.442	0.082	-0.213
Variance Local ClusteringC	0.101	0.058	0.031	1.395

Goodness-of-fit results for the bivariate network ‘Resource sharing (B) & Cooperative projects (C)’.

Statistic	Observed	Mean	Std. Dev.	t-ratio
EdgeB	39.000	38.550	13.983	0.032
2-StarB	182.000	173.919	98.245	0.082
3-StarB	353.000	282.039	206.876	0.343
TriangleB	18.000	18.427	11.760	-0.036
AAS-B(2.00)	89.501	90.081	43.351	-0.013
AKTB(2.00)	39.375	39.742	22.379	-0.016
A2PB(2.00)	142.156	132.398	66.117	0.148
T3uBB-expertise	6.000	6.972	5.439	-0.179
T2uB-expertise	26.000	28.455	19.785	-0.124
T1uB-expertise	38.000	39.377	25.573	-0.054
O3uB-expertise	53.000	54.043	34.623	-0.030
O2auB-expertise	166.000	165.557	98.960	0.004
O2buB-expertise	74.000	72.848	42.193	0.027
O1auB-expertise	136.000	124.967	72.494	0.152
O1buB-expertise	229.000	226.935	127.574	0.016
RbB-expertise	17.000	16.922	6.994	0.011
RB-expertise	52.000	50.444	18.970	0.082
Matching B-cat	15.000	14.646	5.621	0.063
Mismatching B-cat	24.000	23.904	9.494	0.010
EdgeC	62.000	61.633	18.710	0.020
2-StarC	443.000	416.091	212.758	0.126
3-StarC	1150.000	1009.111	684.262	0.206
TriangleC	65.000	62.849	38.626	0.056
AAS-C(2.00)	174.353	170.253	67.761	0.061
AKTC(2.00)	92.961	91.075	43.030	0.044
A2PC(2.00)	249.680	233.969	87.366	0.180
T3uBC-expertise	20.000	26.005	17.558	-0.342
T2uC-expertise	93.000	103.059	65.526	-0.154
T1uC-expertise	137.000	138.277	85.130	-0.015
O3uC-expertise	127.000	136.697	74.375	-0.130
O2auC-expertise	400.000	413.257	215.065	-0.062
O2buC-expertise	181.000	178.284	92.047	0.030
O1auC-expertise	307.000	306.931	157.644	0.000
O1buC-expertise	576.000	549.605	278.401	0.095
RbC-expertise	28.000	27.857	9.184	0.016
RC-expertise	83.000	81.586	25.295	0.056
Matching C-cat	21.000	20.787	6.594	0.032
Mismatching C-cat	41.000	40.846	13.280	0.012
EdgeBC	33.000	32.601	12.885	0.031
2-Star-BC	560.000	541.734	288.970	0.063
3-Star-BBC	1486.000	1309.170	918.946	0.192
3-Star-BCC	2219.000	2003.278	1371.689	0.157
Triangle-BBC	88.000	85.761	52.481	0.043
Triangle-BCC	132.000	129.222	78.234	0.036

Isolate-BC	2.000	0.719	0.989	1.295
AKTBCB(2.00)	62.531	61.491	33.140	0.031
AKTCBC(2.00)	61.992	61.176	28.984	0.028
mr-expertise	16.000	15.924	6.823	0.011
mb-expertise	47.000	44.928	18.006	0.115
Matching EdgeBC-cat	12.000	11.755	5.060	0.048
Mismatching EdgeBC-cat	21.000	20.846	8.877	0.017
Std Dev degree distB	2.742	2.266	0.535	0.891
Skew degree distB	1.207	0.438	0.453	1.698
Global ClusteringB	0.297	0.293	0.089	0.042
Mean Local ClusteringB	0.284	0.262	0.105	0.213
Variance Local ClusteringB	0.098	0.072	0.035	0.751
Std Dev degree distC	3.760	2.955	0.643	1.252
Skew degree distC	0.412	0.206	0.404	0.511
Global ClusteringC	0.440	0.414	0.099	0.267
Mean Local ClusteringC	0.424	0.397	0.121	0.228
Variance Local ClusteringC	0.101	0.063	0.029	1.319