D4.5 Behavioural economics

Assessing Food Waste innovations diffusion through ABM models – Insights from Italy and the Netherlands

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Authors

Matteo Masotti, University of Bologna, Italy

Lusine Aramyan, Wageningen Economic Research, NL

Katja Logatcheva, Wageningen Economic Research, NL

Simone Piras, University of Bologna, Italy

Simone Righi, University of Bologna, Italy

Matteo Vittuari, University of Bologna, Italy

Marco Setti, University of Bologna, Italy

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List of abbreviations

ABM	Agent-Based Model
EU	European Union
FSC	Food Supply Chain
FW	Food Waste
FWM	Food Waste Model
FWP	Food Waste Prevention
FWR	Food Waste Reduction
WP	Work Package

1 Executive summary

REFRESH is an EU research project dedicated to contributing to the achievement of the Target 3 of Sustainable Development Goal 12, which aims to halve per capita food waste at the retail and consumer level as well as reducing food losses along the food chain by 2030. Partners across Europe are collecting data on methods to reduce or repurpose food waste.

In developed countries an estimated 30 to 40% of food is wasted. About half of this waste stems from consumers, while the remaining part is lost through the other phases of the Food Supply Chain (FSC): farm practices, transport and processing, and the retail sector (Godfray et al. 2010; Gustavsson et al. 2011). To meet target 12.3 of the Sustainable Development Goals, a better understanding of the drivers of food waste are needed, both at the consumer and at the retail level. More importantly, the effectiveness of interventions designed to reduce food waste at every level of the FSC needs to be assessed.

Research on food waste faces several issues. On one side, the large number of factors influences the behaviour of the actors in the Food Supply Chain, on the other side, food waste research often lacks reliable data on the amounts of food wasted along FSC. One of the possibilities to reduce food waste is the adoption of tailored innovations aiming at prevention and reduction of food waste. Currently there are many initiatives in this direction. However, there is a lack of information on effects of such interventions, since they are usually not large-scaled but have more of the local character. In this work, issues related to the complexity of the food waste phenomenon and to the lack of reliable data are tackled using a simulation approach.

In order to overcome those problems related to data availability, an Agent Based Model (ABM) was used as a tool to assess the adoption of food waste reduction innovations among retailers. ABMs are effective tools for the analysis of market evolutions where behavioural factors (i.e. specific biases of single actors and interactions among actors) and temporal dynamics (interaction among variables or actors across time) plays a strong role.

Here, results of simulations based on a fully-developed Agent Based Model, presented in Grainger et al. (2018) and described in detail in section 4, are outlined. Simulations are focused on the Italian and Dutch market for fresh fruit and vegetables, with the aim to describe the main drivers for innovation adoption for food waste reduction at the retail level. In particular, in this work the ABM will be used to simulate the impact of two innovations: an active packaging, that increases the shelf life of fresh fruit for the Italian market, and a misting technology, used in the Dutch grocery retailers to increase the durability of fresh fruit and vegetables.

Aim of this study is to analyse the main factors that influence the adoption of innovation aiming at a reduction of food waste at the retail level, with a focus on the adoption on technological innovations. To do so, and to overcome the lack of data, a set of simulations is conducted, considering different characterizations of consumers (such as their sensitivity to the price of goods and their level of awareness

about the existence of a food waste reduction technology) and of the grocery market (e.g. the presence of strong connections among retailers).

Results show that the adoption by retailers of innovations aimed at reducing food waste is influenced by a number of factors, which are not only of strictly economic nature. In particular, the presence of strong connections among retailers and, to a lesser extent, a high level of awareness about the existence of food waste reducing innovations among consumers have a prominent role in the retailers' decision to adopt food waste reduction innovations.

Findings from the ABM simulations can be useful to assess the impact of policy interventions, addressing the factors that influence the adoption of food waste reduction innovations. This can contribute to reduce food waste at the retail level and, as a consequence, also at the consumer level.

2 Introduction and objectives

Food waste (FW) is a widespread and complex problem, which relates to the functioning of the food supply chain (FSC) as a whole. Estimates suggest that, in the EU-28, annual FW amounts to 88 million tonnes, i.e. 173 kilograms per person (Stenmarck et al. 2016). Food waste has become a major global concern because of its diversified and interconnected implications on the different stages of the FSC (Canali et al., 2017; Parfitt et al., 2010).

While the highest quantity of food waste is generated at the household level, grocery retail sector requires particular attention (Piras et al., 2016; Aramyan & Kuijper, 2009), because of its potential in terms of FW reduction (Parfitt et al., 2010) and its influence on the entire FSC (Aramyan & Kuiper, 2009).

Moreover, grocery retail sector has a strong influence on the food chain, representing an interface among different segments of the FSC having an impact on food waste reduction both exerting upward pressure on suppliers up to agricultural production (Parfitt et al., 2010), and by influencing consumers' behaviour (Aramyan & Kuiper, 2009, Piras et al., 2016). Results of grocery retail research on FW point out that innovations can play a major role to avoid and reduce FW (Aramyan & Valeeva, 2016; Canali et al., 2017; Mathijs, et al., 2011; Parfitt et al., 2010; Piras et al., 2016; Bromley, 2016; European Parliament, 2011).

One of the possibilities to enhance food production efficiency is the adoption of tailored innovations aiming at prevention and reduction of food waste, as the introduction of new packaging systems improving food management and ensuring shelf life extension, use of misting technologies, implementation of improved storing units and other product and process innovations (Aramyan & Valeeva, 2016; Canali et al., 2017; Mathijs et al., 2011; Parfitt et al., 2010; Piras et al., 2016; Bromley, 2016; European Parliament, 2011).

Although innovations could play a crucial role in preventing and reducing food waste, as highly emphasized by Canali et al. (2014), they still have to be economically feasible in order to be adopted by decision makers in the food supply chain. Thus analysing the economic factors affecting the decision makers' decision to adopt the innovations to reduce and prevent food waste is of high importance.

However economic factors by themselves (such as economic incentives and cost-benefit analysis described by neoclassical economic theory), cannot fully explain the behaviour of firms when deciding whether or not to adopt an innovation. In some cases, innovations are not adopted even though it would have resulted in significant economic benefits, while in another cases companies have adopted innovation despite this resulting in economic losses for the firm. In this case an approach based on behavioural economics theory can help to provide better explanations of the underlying decision of firm operators to adopt or not certain innovations.

Behavioural economics has been adopted for this study because it goes beyond standard economic theory and studies empirical behaviour of people and businesses by considering a complex combination of social, psychological and cognitive factors that influence business and economic decisions (Piras et al., 2016). The

same authors show that this field provides typologies that influence businesses (like grocery retailers and suppliers) to adopt an innovation or not. Therefore, as it combines the needed disciplines selected for this study, theories and concepts will be analysed and selected from behavioural economics.

Recent research on food waste reduction (FWR) innovations has been mainly generalised to the whole FSC. Specifically, within grocery retail research, the main focus has been on quantifying and recovering FW (Lebersorger and Schneider, 2014; Girotto et al., 2015; BRC, 2016; FWRA, 2016). Studies that focus on a particular FWR innovation, like Broekmeulen and van Donselaar (2016) and Buisman et al. (2017), are concerned with its benefits and on its implementation. Piras et al. (2016) researched factors that could influence the adoption of FWR innovations among suppliers and retailers. However, they do not provide empirical information on how these factors interact or which factors are more important. at Food waste at retail level has many different drivers: undesirable customer behaviour and erratic demand, inefficient store operations and replenishment policies, strict product/cosmetic quality requirements of both retail organizations and customers. These drivers also differ significantly depending on store format and size and on product typology and characteristics (Teller et al., 2018, Canali et al., 2017; Broekmuelen & van Donselaar, 2016). Furthermore, grocery retail is also a simpler sector to study from an economic point of view, as it is more standardised and has fewer, but more concentrated actors than the other FSC segments (Piras et al., 2016).

Despite the previous research done, there is still a knowledge gap in empirical, interdisciplinary understanding of the factors that allow FWR innovations to be adopted and diffused successfully among grocery retailers. At the same time, while commonalities among the different store formats can be found in terms of FW, horticultural products represent the category that registers the highest levels of waste at the retail level (Cicatiello et el. 2017; Beusang et al. 2017).

Therefore, the **objective** of this study is to analyse the determinants of the adoption of FWR innovations among grocery retailers with a focus on horticultural products.

3 Theoretical background

3.1 *What factors influence the decision to adopt a FWR innovation?*

Innovation is recognised to play a central role in creating value and competitive advantage (Baregheh et al., 2004). Innovations are to an increasing extent seen as the result of an interactive process of knowledge generation, diffusion and application (Todtling et al., 2009).

In this study, innovation is defined as "the process of translating an idea or invention into a good or service that creates value or for which customers will pay" (Business Dictionary, 2017). According to this definition, an idea can be called an innovation if it is replicable at an economical cost and satisfies a specific need.

Innovation adoption takes places in two stages: at the first stage, a firm decides to adopt innovation or not; the second stage shows the speed of innovation adoption, otherwise called diffusion of innovation. Hereby, there is a need to distinguish between the innovator (who proposes the innovation) and the adopter (who adopts the innovation), since not all individuals in a social system adopt innovation at the same time (Rogers 1983). Innovators may be classified into five adopter categories based on their degree of innovativeness, i.e. the extent to which they are ready to adopt an innovation earlier than the others. Adopter categories are innovator-adopters, early adopters, early majority, late majority and laggards.

Technological innovations can be related to products or processes. Product innovations involve the creation of new products or services through a process in which ideas are finally produced and commercialised by the firm. On the other side, through process innovations, the firm develops or modifies new products or services. In general, process innovations are driven by cost-reduction concerns, while product innovations are aimed at product differentiation (Martinez-Ros, 1999). Finally, the evolution process from invention to innovation assumes that the innovator has the financial means, market knowledge, as well as specific skills (Winter, 2006).

In this study the factors affecting the adoption of technological innovation have been extensively analysed. The main findings from factors affecting the decision to adopt the technological innovation are summarized in Table 1 below.

Table 1 Summary table: main findings from technological innovation

Factors affecting the decision to adopt technological innovations	Major references
Economic incentives costs/finance, and to risks associated with the costs: for instance, investing in innovations to reduce food waste may not be (very) cost-effective or pay-back time to investments may be long;	Marra et al., 2003; del Río Gonzalez, 2005; Montalvo, 2008; Long et al. (2016), Cullen et al., 2013; Faber and Hoppe, 2013; Luthra et al., 2014
Consumers' willingness to pay/ acceptance of the innovation	Henson, 1996; Blackholly and Thomas, 1989; Reinstaller, 2008; Ceschin, 2013 ; Martinez and Briz, 2000
The speed of action (how fast the innovation takes up and can be spread;)	Fagerberg, 2005; Avolio et al., 2014
Territorial specificities, where the strength of the social, legal and cultural context plays a crucial role	Abadi Ghadim et al., 1999; Klerx et al., 2012; Avolio et al., 2014

Technological innovation can contribute substantially to prevent and reduce food waste (Canali et al., 2014). Examples of such technological innovations include the development of new technologies for storage, refrigerators/cooling, the development of new equipment for harvesting and transporting food along supply chain, electronic ordering systems, advanced packaging etc. As described in table 1 several economic factors play a crucial role in business decision to adopt the innovation.

One of the most important factors is investment costs and all factors related to it, such as risks associated to sunk costs, long pay-back periods, high initial investments, poor access to capital, small size of the company with insufficient resources. According to Long et al. (2016), the cost of many technological innovations is prohibitive, especially early in the diffusion process, due to difficulties in initial commercialisation efforts. The expenses of establishing production facilities, as technology developers transform into technology producers, often imply that profits are hard to obtain and increase the costs of the innovative product or service (Cullen et al., 2013; Faber and Hoppe, 2013; Luthra et al., 2014). The capital life (long or short) of a current technological stock also affects the relative cost of innovations, where a long capital life is damaging the relative economic benefits of investments in new innovations (del Río Gonzalez, 2005; Montalvo, 2008).

Another crucial factor is the willingness to pay and/or consumer acceptance of a new technology. Even if the retailers decide to invest in an innovative technology to reduce food waste, there is still a question whether it will find an adequate response from final users. This applies to new technologies, new processes and new products which are directly communicated to consumers. Blijlevens et al. (2009)

states that companies that are able to communicate a certain meaning (e.g. prestige) through the appearance of a product design can create a competitive advantage in the market and increase the product's chance of success.

Finally, the adoption and the diffusion of technological innovations is influenced by the territorial specificities with legal cultural and economic context. In case of food waste reduction possibilities, the adoption and diffusion of technological innovation can have different patterns in different EU countries depending on national policies supporting such, economic situations and the culture (Aramyan and Valeeva, 2016).

3.2 *What behavioural economics can tell about the adoption of FWR innovations?*

Behavioural economics is a powerful theoretical instrument for understanding the complex factors influencing real economic decisions, since it investigates the consequences of social, psychological and cognitive factors on economic behaviour (Piras et al. 2016).

A broad classification of behavioural economics literature can be based on which of the following main assumptions of the standard economic theory it challenges: the assumptions of rationality and of selfishness (search for profit maximization) of the economic agents, and the assumption of irrelevance of the social environment where these agents operate (Piras et al. 2016).

This clustering derives from Piras et al. (2016), where an extensive literature review has been carried out to explain the behavioural economics and to identify behavioural typologies and interrelationships of food businesses and relate it to food waste (Piras et al. 2016). The behavioural typologies used in the current study to identify the factors underlying the decision of the firms to adopt certain innovation in reducing food waste are based on the study carried out in the cited paper. Below a short explanation on these groups is provided:

Challenging the assumption of rationality of the economic agents

The classical economic literature assumes that economic agents have rational preferences (Mas-Colell *et al.* 1995), rational expectations about future events (Muth 1961), and that they assess uncertain situations in accordance with the expected utility theorem (Von Neumann and Morgenstern 1953). Actual individual behaviour, deviates from such assumptions. Businesses may deviate from full rationality either because they implement progressive learning, since they have a limited foresight, because they cannot properly process information and risk, being affected by cognitive biases, or because they are time-inconsistent (Piras et al. 2016).

Limited foresight impacts strongly business decisions to invest in costly innovation. Thus in presence of limited foresight, firms tend to adopt innovations later (Chen and Ma, 2014), while learning reduces adoption times. Another type of non-rational behaviour is the inconsistency of preferences over time (Loewenstein, 1988). *Time-inconsistent* agents tend to change their mind from virtues (small immediate costs in exchange for a large delayed reward) to vices (small immediate reward for a high delayed cost) as the moment of consumption approaches (Loewenstein and

Kalyanaraman, 1999). Because of this issue of time inconsistency of choices between vices and virtues, firms are more likely to start food-saving investments if they take this decision simultaneously with others through a pre-commitment, and if the investment cannot be recovered as the moment of the payment approaches, due to an irreversible pre-commitment (having set penalties for misbehaviours) (Piras et al. 2016).

Commitment leads firms to respect their engagement, fosters collective action, and is associated with pro-social behaviour (Lapointe and Vandenberge, 2015). Committed firms are also preferred as partners, especially if an alliance is difficult to manage but its outcome easy to evaluate (Shah and Swaminathan, 2008). Moreover, behavioural factors like regular information sharing, transparent negotiations, restraining from the use of market power and solving the conflicts in a friendly way foster commitment more than financial incentives.

Information processing is also a very important factor in adoption of innovation: since irrelevant information can lead to sunk-costs, a sunk-cost fallacy may lead businesses of the food sector to either keep investing in unviable innovations (in order not to lose the investment: loss aversion), or not to invest in new ones because of past unsuccessful in-vestments.

Thus behavioural factors, such as regularly sharing information and communications, carrying out regular negotiations, transparency of the process of price determination, restraining from the use of power, and solving the conflicts through friendly and informal mechanisms, are more important than price levels in fostering commitment of small firms (Piras et al. 2016). On the other side, larger companies (in the food sector) tend to acquire information about innovations from experts or using the internal personnel resources.

Finally, small companies rely more on informal channels, such as business interrelationships. Imitation is a powerful and widely-used heuristics when innovation is concerned (Andrews and Johnson, 2016). The companies' perception of imitation and of the innovation adoption as a threat or as a potential gain are the determinants of the timing of innovation adoption and of the decision of the type of heuristics to be used (Piras et al. 2016).

Challenging the assumption of the selfishness of the economic agents

The assumption of selfishness assumes that maximizing payoff is the only thing that matters in economic decisions (Arrow and Debreu, 1954; Mas-Colell, Whinston and Green, 1995).

Instead, real-world firms may forgo profit opportunities once they have achieved a sufficiently high welfare (Dixon, 2001), and be concerned about values and beliefs (Lincoln, Pressley and Little, 1982) or about other people's welfare (Engelmann and Strobel, 2004) However, businesses may adopt other decision strategies, or be influenced by specific or socially shared values, beliefs, and norms, including pro-environmental concerns, rather than simply maximizing their profit. Moreover, their utility may be affected by the utility of other agents: in this case, they show either pro-social or anti-social behaviours, like altruism (Piras et al. 2016).

The level of profits that a business considers "s*atisfactory"* depends on its historical returns, the performance of its peers, its most recent profit levels (salience effect),

and on visible characteristics of the object of choice rather than hidden ones (Berg, 2014; Shah and Swaminathan, 2008; Piras et al. 2016).

According to literature, small businesses and socially-oriented firms tend to adopt satisficing behaviour oftener than their counterparts. Altruistic behaviour is driven by small companies' awareness of need, the solicitation by others, a costs-benefits analysis, and the perceived efficacy of their action (Piras et al. 2016); Besides, businesses may prefer or discard some options because of their values and beliefs (Lincoln, Pressley and Little, 1982).

Concerning pro-environmental values, they can foster pro-environmental behaviour that can be of three types: curtailing (reducing inputs), increasing efficiency, or political (advocacy) (Chen, 2015; MacDonald and She, 2015). As stated in Piras et al. 2016, micro-businesses engaged in pro-environmental activities prefer to remain as independent as possible from the markets, seek lifestyle regards rather than financial gains, or show resistance to opportunity-seeking. More specifically, reuse and recycling behaviour is motivated by reputational concerns. and social normative pressure: so it is more likely to be adopted if it is visible. On the other side, waste reduction behaviours are driven by intrinsic motivations (idiosyncratic characteristics of the individuals) (Piras et al. 2016).

Finally, socially-oriented producers maximize on value creation, while adopting a satisficing behaviour as for value capture. Results from Piras et al. 2016 has concluded that although individual thresholds of innovation adoption are heterogeneous and affected by social norms, they are influenced by them and by sociological variables (social class, education, occupation), and may change in case of great emotional shocks.

Challenging the assumption of the irrelevance of the social environment where these agents operate

Standard economic theory assumes that individuals take their decisions in isolation. Nevertheless, social forces and the social environment play a key role for real-world agents in shaping their attitudes and decision making process (Putnam, 1995; Jackson 2008). This isolation hypothesis could be challenged by several aspects.

First of all, inter-business relations are not anonymous: issues such as trust, honesty, and inequality aversion (preference for fair decisions and outcomes), and their implications for business interrelationships are fundamental elements for the definition of firms' behaviour. Moreover, the impact of reciprocity, reputation, and of business position relative to their peers is essential. Finally, networks, and other forms of co-operation, which arise from these business characteristics, also have a fundamental impact on companies' behaviour.

According to those assumptions, relations between companies tend to be more stable and long-term-oriented due to trust (Sharif, Kalafatis and Samouel, 2005; Suvanto, 2012) and to the adoption of fair behaviours (Rabin, 1993). Thus the level of trust among partners increases as the duration of a cooperative alliance increases. In some circumstances, if a prior alliance was not able to build high levels of trust, its former members tend to avoid creating new linkages among each other: current partners and complete strangers are preferred to acquaintances, especially if radical innovations are concerned.

The process of trust-building varies with a firm's size, management, and alliance type.

While small businesses assign a great importance to personal interrelationships, and to informal communication; large ones focus more on formal governance of alliances (contracts, communication events, etc.), which is often alternative to trust. Trust and cooperation are two mutually reinforcing phenomena, but an initial risk-seeking attitude (cooperation without trust) is needed in order to start the process.

On the other side, reciprocity (defection and reduced trust in exchange for defection) is not successful in the first phases (Piras et al. 2016). Cooperation without trust may be more stable, especially in developed countries, since it pushes people to establish well-defined institutions (e.g., network regulations) in order to reduce risk.

The combination of reciprocity and possibility of building a reputation generate cooperation even among competitors (Trivers, 1971), or if selfish individuals are a majority (Fehr and Schmidt, 1999). Reciprocity can be either direct or indirect. Direct reciprocity works if the probability that the same agents meet again is higher than the cost-to-benefit ratio of the altruistic act (Falk and Fischbacher, 2000; Nowak, 2006; Rabin, 1993). Indirect reciprocity occurs if the probability of knowing someone's propensity to cooperate exceeds the cost-to-benefit ratio of the act (Nowak and Sigmund, 2005).

Another fundamental aspect of the importance of social relations is the reputation. Reputation may also play a role in relation to food waste. While reduction of food waste may result in a drop in the margins of retailers, the resulting positive reputation may lead consumers to purchase from them.

Finally, companies create alliances or networks for different purposes, like increasing their bargaining power (Das and Teng, 2000), or sharing and reducing R&D costs (Goyal and Joshi, 2003). A key driver of cooperation is the shared understanding of the rules guiding firm behavior (habits, industrial standards, etc.), which arises through recurrent interactions and becomes embedded in the alliance (Mouzas and Henneberg, 2015).

With respect to processors and retailers, and to the market conditions where they operate, the following two main behavioural schemes are assumed, associated to businesses' structural typologies:

- large businesses (e.g., stock exchange processor companies, large-scale retailers) are characterized by indirect reciprocity, prefer formal coordination schemes, and tend to adopt innovations first;
- small firms (e.g., local processors, family firms, traditional shops) adopt a satisficing behaviour, and imitate the innovation patterns of their most successful peers.

Table 2: Summary table: considered behavioural economics approaches

Behavioural typology	Major references
Challenging rationality of the economic agents	Chen and Ma, 2014; Loewenstein, 1988; Read, Loewenstein and Kalyanaraman, 1999; Lapointe and Vandenberge, 2015; Shah and Swaminathan, 2008; Andrews and Johnson, 2016
Challenging selfishness of the economic agents	Dixon, 2001; Engelmann and Strobel, 2004; Berg, 2014; Shah and Swaminathan; 2008; Lincoln; Pressley and Little, 1982; Chen, 2015; MacDonald and She, 2015; Piras et al. 2016
Challenging irrelevance of the social environment where these agents operate	Putnam, 1995; Jackson 2008; Sharif, Kalafatis and Samouel, 2005; Suvanto, 2012; Rabin, 1993; Trivers, 1971; Falk and Fischbacher, 2000; Nowak, 2006; Rabin, 1993; Nowak and Sigmund, 2005; Das and Teng, 2000; Goyal and Joshi, 2003; Mouzas and Henneberg, 2015; Piras et al. 2016

4 Methodology

4.1 *Grocery retail classification*

4.1.1 Different retail formats targeting different consumer groups

Customers formulate their experience during their grocery shopping in terms of satisfaction. Customers evaluate the retailer offer by combining different attributes, of which price (see McGoldrick, 1990) and product (quality, assortment and presentation) (Lindquist, 1974, Anselmsson, 2006) are considered as the core attributes. Other characteristics of the retailer include its visual environment, store lay-out and design, and customer service (Spies et al., 1997, Arnold, 1997). Retailers' growth strategies result in emerging of different retail formats targeting different consumer market niches. The current grocery landscape formats are differentiated by their location, sales area, types of brands offered including the availability of supermarkets brands, in-store facilities, convenience to customer, etc. Retailer's pricing strategy whether or not combined with a certain product policy largely contributes to the positioning (McGoldrick, 1990).

Previous research has revealed a connection between consumer characteristics and choice of retail format. Prasad and Aryasri (2011) provided a detailed study on the effect of shoppers' demographic, geographic and psychographic dimensions on their grocery retail format choice behaviour in India. They show significant association between shoppers' choice for a certain retail format, like convenience store, supermarket, hypermarket or a traditional neighbourhood store, and their gender, occupation, education, income, family size, distance travelled to store, and their psychographic profiles based on their values, interests, opinions, and shopping orientation. Szolnoki and Hoffman (2014) show that the different sales channels for wine, like discount shop, supermarket, wine store, at the winery, at the co-operative, via mail order/internet, are able to identify their regular customers based on their socio-demographic profiles that include their gender, age, education and income.

4.1.2 Different retail formats and links to innovation behaviours and food waste targeting different consumer groups

An appropriate classification of the European retail can assist to link different retailing forms to:

- the amount of food waste
- innovation behaviour

For example, the type and the volume of merchandize can be linked to the absolute and relative amounts of food waste generation per outlet. In the retail landscape there is differentiation in both, depending on which outlet is considered. Also innovative behaviour can differ between the types of retail. A DG Competition study (2014) about the economic impact of modern retail on choice and innovation in the EU food sector shows different evolution patterns in new product launches in supermarkets, hypermarkets and hard discounters in different time periods.

Classification types

Guy (1998) reviews the methods of classifying retail outlets and areas devoted to retailing, in the geographical and town planning literature, and describes the following types of classification:

- Classification by type of goods: specialized or mixed store.
- Classification by shopping trip purpose: e.g. convenience shopping (includes food purchasing) and comparison shopping.
- Classification by size and type of store: e.g. supermarket, hypermarket.
- Classification by store owner: e.g. cooperatives, small or large private multiple outlets retailers.

These four general methods are used by others for further classification in the different European countries, see for example Fertal'ova (2005) using the methods on Slovakia and Czech Republic. Guy (1998) concludes that of these methods, some might be inclusive and others not. The food super/hypermarket can be defined by its range of merchandise, ownership, type, size and internal design, or a combination of these attributes. Sales area is more indicative of the volume of merchandise in a store.

In the table below the expected relevance of the Guy (1998) methods is shown for differentiating the amount of food waste and innovation preventing food waste per store type.

Table 3: FWR innovation per store type

Classification	Food waste	Innovation preventing food waste
Type of goods	*Highly relevance, e.g. perishable versus non-perishable goods*	*High relevance. Different economic risks of wasting products per type of food*
Shopping trip purpose	Low relevance, food shopping is included in convenience shopping	Low relevance, food shopping is included in convenience shopping
Size and type	*High relevance. The size is indicative for the amount of merchandize, the type is indicative for the range of products*	*High relevance. Different technology at different types of outlets*
Store owner	Low relevance. Assumed that economic incentives are comparable for each type of owner	Low relevance

DG Competition study (2014) distinguishes between the 'traditional' and 'modern' retail. Traditional retail can be characterised largely as small, independent and often family-owned businesses with non-organised distribution channels. These include mixed grocery shops, but also food specialist outlets with a focus on one type of foods (bakery, butcher). However, for the latter, there are some branded specialist outlets that operate on the retail market, but their number is rather limited. Convenience shops are both branded (e.g.7-eleven) and independent (corner shops, family-owned) with limited assortment of grocery products.

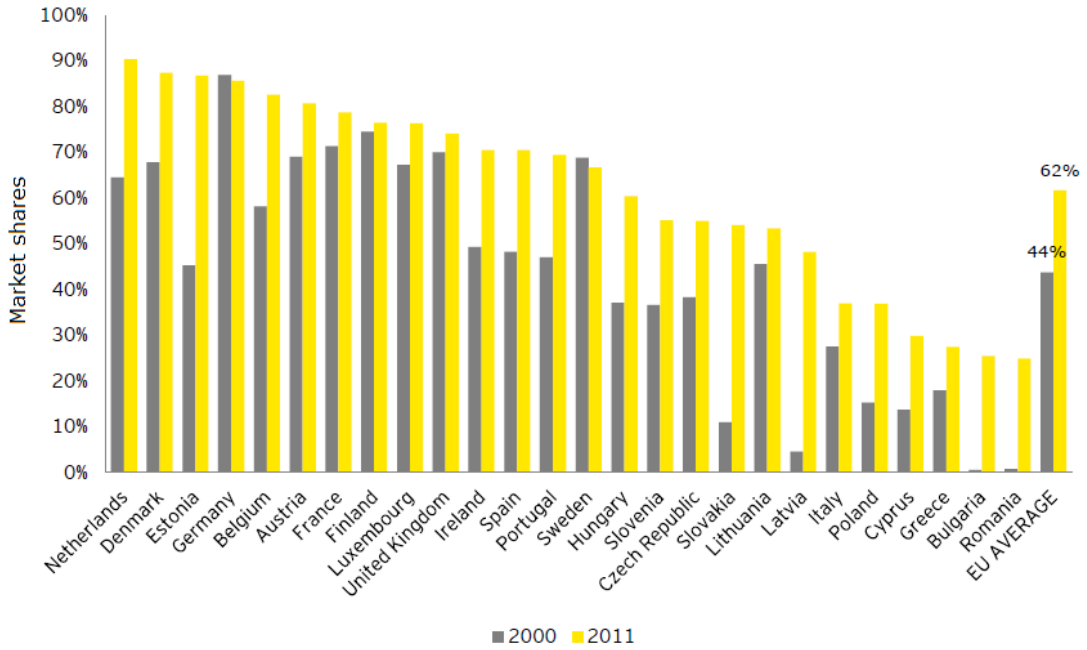
Furthermore, DG Competition study (2014) mentions retail outlet type characteristics like the sales area, the food sales area, the number of stock-keeping units.

Modern retail is associated with a number of different characteristics that include:

- Group of shops with the same banner integrated in a network,
- Shop size and format (hypermarkets (>= 2 500m²), supermarkets (400 -
- 2 499m²), discounters (all sizes)),
- Assortment of goods offered (the number of stock-keeping units - SKUs, different product categories),
- Self-service formats,
- Technology and equipment,
- General business practices (logistic, marketing…) (DG Competition (2014).

Modern retail prevails in most EU countries, with an EU average of 62% in 2011 and increasing.

Figure 1: Evolution of the market share of modern retail compared to total edible grocery market (2000-2011)



Source figure: DG Competition (2014)

Hypermarkets have a broader range of non-food product assortment than supermarkets, which includes household items and appliances. Discounters have a high share of area dedicated to food. There has been some development in the number of stock keeping units (SKU's) offered by each type of outlet starting from the 1990s, i.e. the number of SKU's offered in a supermarket increased.

A comprehensive characterization of retailers

Findings from Guy (1998) and DG Competition (2014) are integrated, updated and supplemented with the numbers for the most recent period, e.g. for the product range, from various internet sources[1]. We get the following combinations of outlet types and characteristics as summarized in the table 4 below.

[1] See for example: https://www.slideshare.net/michealbrickman/types-of-retailers; http://www.carrefour.com/sites/default/files/carrefour_investor_presentation_2017.pdf; https://www.atkearney.com/documents/10192/481098/What_Traditional_Retailers_Can_Learn_from_the_Discounters.pdf/e5184e65-4755-4752-ae58-d78ee0e2ad5f

Table 4: Sales area, food stock keeping units and type of goods in the traditional and modern food retail

Traditional or modern	Food outlet	Price level	Sales area (m^2)	Food sales area, %	Food Stock keeping units (SKU)*	Type of goods
Traditional	Traditional retail shops*	High	< 250	80-90	1,000-2,000	Mixed
Traditional or modern	Convenience shop, corner shop	High			2,000-5,000	
(mostly) Traditional	Specialist shop (Butcher, baker, liquor store, etc.)*	High		100	<1000	Specialized
Modern	Small supermarket	Middle	250-1,000	80	5,000-10,000	Mixed
	Small Discounter	Very Low		90	1,000-3,000	
	Large supermarket	Middle	1,000-2,500	80	10,000-20,000	Mixed
	Large Discounter	Very Low		90	1,000-3,000	
	Hypermarket	Low	>2,500	50	<500,000	Mixed

Sources: Guy (1998); Kulke (2006); DG Competition (2014); * updated or added based on various online sources. Adaptation: authors

On the basis of this literature review, the following typologies of retailers have been identified for this study, starting from data of the IGD database (© IGD Services Limited[2]). Typologies of stores have been selected according to their market size, so a retail brand can include stores of different size.

Table 5: Typology and average sales areas of grocery retailers in Italy and the Netherlands

Size	*Typology and average sales area (IGD)*	
	Italy	**the Netherlands**
Small (<500 m²)	Convenience & forecourt (260 m²) Frozen Specialist (490 m²)	Convenience & forecourt (148 m²)
Medium (501-1,000 m²)	Food discount (666 m²); Superstores & supermarkets (791 m²)	Food discount (924 m²) Variety discount (1,000 m²)
Large (>1,001 m²)	Wholesale (2,699 m²) Compact Hypermarket (3,094 m²) Cash & carry (3,252 m²) Hypermarket (6,353 m²)	Superstores and supermarkets (1,054 m²) Supermarkets and neighbourhood (1,200 m²) Cash and Carry (6,809 m²)

Considering this classification of grocery retailers based on the average surface of their sales area, the description of the Italian and the Dutch grocery market structures is presented in table 6

Table 6: Grocery market structure and market shares in Italy and in the Netherlands

Size (average)	*Number of Stores*		*Share of stores per size*		*Market share*	
	Italy	**the Netherlands**	**Italy**	**the Netherlands**	**Italy**	**the Netherlands**
Small (<500 m²)	4,449	229	25.05%	5.12%	25.80%	0.85%
Medium (501-1000 m²)	12,693	1,281	70.67%	28.64%	44.70%	18.91%
Large (>1001 m²)	769	2,963	4.28%	66.24%	29.50%	80.24%

[2] See: igd.com

4.2 *A focus on horticultural products*

According to Laurentiis et al, (2018) fresh fruit and vegetables contribute to almost 50% of food wasted by households in the EU. Some of the reasons behind this consistent value are: fruits and vegetables are highly perishable products (together with meat and fish), therefore, compared to more stable commodities (e.g. pasta, rice, sugar) it is more likely that they will not be consumed in time. Furthermore, fruits and vegetables are relatively cheap commodities (e.g. compared to meat and fish) and therefore it could be expected that consumers are less averse to let them spoil (Laurentiis et al, 2018). Next to it, fresh fruits and vegetables tend to have short shelf-life (5–14 days), little or no primary packaging, cardboard and plastic trays usually used for secondary packaging and are sensitive to temperature changes (Mena et al, 2011). Besides, fruits and vegetables damages happen often due to poor handling, particularly in store sometimes by customers (e.g. bruised fruits). In addition, fruit and vegetables is an interesting category from an environmental perspective because it tends to have higher levels of waste (partially balanced by a low environmental footprint if compared to meat and dairy products) due to their short shelf-life (Mena et al., 2011).

4.3 *Two countries and two innovations*

In order to address the objective of the study two types of technological innovations have been considered in two countries, Italy and the Netherlands.

4.3.1 Case study of Italy: an active packaging to increase shelf life

Grocery retail market in Italy

The Italian grocery market is represented by a wide range of stores typologies, ranging from the small neighbourhood store to the large supermarket. This study takes into account only the stores which belong to retail groups, while data on independent stores are not included.

According to IGD data (© IGD Services Limited[3]) Italy registers 17,911 grocery stores, belonging to 21 retail groups.

In terms of number of stores by typology, the most represented category is the superstores and supermarkets, with 7,939 selling points (44% of the total number of stores). Superstores and supermarkets are followed by food discount (4.754, 26.5% of total stores) and convenience and forecourt store (4,458, 24.8% of the stores). So, according to table 6, the Italian grocery market composition is 25% of small retailers, 71% of medium retailers and 4% of large retailers.

Concerning market shares, small grocery retailers are entitled of almost the 26% of total sales, medium companies register the 45% of sales, and large scale retailers cover almost the 30% of total grocery sector sales.

[3] See: igd.com

The active packaging technology

One of the most relevant reasons of fresh horticultural products waste both at the retail level and for the households is the spoiling due to the end of shelf life.

A way to tackle this problem is the improvement of packaging of fresh fruit and vegetables, to contrast the action of natural elements which accelerates the degradation process of fresh horticultural products.

The innovation considered for the Italian grocery market is a technology called *Imballaggio Attivo* (active packaging) developed by Consorzio Bestack, a consortium of packaging producers based in Forlì, in collaboration with the University of Bologna. This technology is based on the production of corrugated carton packaging for fresh fruit enriched with natural essential oil with an anti-microbial effects, which slow the natural rotting process, giving a longer shelf life to the horticultural products.

Imballaggio attivo has been tested for different types of fresh fruit, in particular strawberries, nectarines and apricots. Results of testing shows different values of weekly food waste reduction for different types of fruits, going from the 11,8% for strawberries to 25.7% for nectarines. The potential food waste reduction for Italy has been estimated, in terms of quantity, in 640,000 to 850,000 tons per year, with a potential economic benefit of 1-1.4 billion euro.

4.3.2 Case study of the Netherlands: a dry misting technology to reduce food waste in grocery retail

Grocery Retail Market in the Netherlands

The grocery retail market involves all the stores that sell groceries. This market is diverse when considering the different types of outlets, which range from chained supermarkets to independent small grocers.

The grocery retail market in the Netherlands is centred within two largest brands, Albert Heijn and Jumbo, which together represent over 50% of the total market share (Distrifood Dynamics, 2017b). 90% of the sales are concentrated among 10 retail chains, which shows that the industry is quite consolidated (Distrifood Dynamics, 2017b; Pinckaers, 2016). The main grocery outlet typology are supermarkets, as they represent about 70% of the total grocery retail outlets in the Netherlands, followed by discounters with 17%, and by convenience stores with 12% (Statista, 2016). Hypermarkets' presence is minimal, with less than 1% of total grocery retail outlets in the country (Pinckaers, 2016).

Moreover, according to table 6, the Dutch grocery market is more polarized than the Italian one. Its composition is 5.1% of small retailers, 28.6% of medium retailers and 66.3% of large retailers.

Finally, according to values of market shares presented in table 6, small grocery retailers are entitled to less than 1% (0.9%) of total sales, while medium retailers register the 18.9% of sales and large scale retailers cover the 80.2% of total grocery sector sales.

The dry misting technology

Fruit and vegetables in Europe are transported in long distances using refrigerated (cold chain) logistics to combat bacterial growth and to preserve other quality aspects, including prevention of decay and stalling ripening processes such as softening etc. Although refrigerated transportation increases the shelf life of the fruits and vegetables before they reach supermarkets, this has however also its downsides. Cold stores draw moisture from the air, lowering the relative humidity. As the produce consists largely of water, the dry air causes the water to evaporate, resulting in dried-out produce and a reduction in weight and freshness (Fresh Demo, 2015). Besides, fresh fruits and vegetables displayed in a store tend to deteriorate quickly as a result of the particularly low humidity in the average produce aisle which causes them to lose a lot of moisture (Fresh Demo, 2015). As an example, lettuce leaves go limp within an hour, which makes the lettuce appear less fresh and crunchy.

To increase the shelf life of fruits and vegetables in the supermarket and consequently by the consumers at home Contronics has developed Dry Misting technology through an innovative technology of ultrasonic humidification. Dry mist technology aims to counteract the deterioration of the fresh produce as a result of low humidity. As the mist evaporates, the humidity rises and the temperature drops naturally. Produce retains its moisture better and stays fresh for longer, without getting wet. An ultrasonic Dry Misting system creates miniscule mist drop lets (1-2µm) called aerosols. Because they are extremely small, they can evaporate immediately above the fruit and vegetables on the shelves, which means that the product doesn't get wet. Instead, an environment with a high relative humidity is created.

Dry Misting technology has been tested for several fresh fruits and vegetables in different countries in the frame of H2020 project "Fresh demo" in 2015.

4.4 Model Description

The introduction of a food waste reduction technology has an impact on the purchasing behaviour of consumers and on marketing strategies of retailers. A useful instrument to model this impact is represented by the Agent Based Models.

The theoretical approach of an Agent Based Model used to assess the factors that promote the diffusion of food waste reduction technology among different markets has been elaborated in Grainger et al. (2018).

In this study the Agent Based Model considers the market for a single food commodity, specifically fresh fruit and vegetables, where the amount of food waste is related to the technologies adopted within the market. The model proposed in this work is based on two typologies of agents, retailers and consumers, with peculiar characteristics which are described further in this section.

Moreover, the considered market operates in imperfect conditions (e.g. asymmetric information among consumers and retailers and between different groups of actors)

and under a quantity-based competition: retailers compete for selling higher quantity of fresh fruit and vegetables.

Concerning retailers, the model considers a set of single companies belonging to three different groups, according to the average size of their sales area. The groups are: small retailers (with a sales area smaller than 500 m²), medium retailers (with a sale area between 501 m² and 1,000 m²) and large scale retailers (companies with a sales area surface of over 1,000 m² and more).

Each retail company can adopt only one of two different technologies:

- A baseline technology that generates a high amount of food waste (initially it is adopted by all companies)
- An innovative technology, which leads to a lower amount of food waste generated. This innovative technology can reduce the food waste generated by consumers at home, as happens for the innovation considered for the Italian market, can prevent or reduce the food waste generated in store (as for the Dutch case, described in section 4.3.2) or can operate in both senses.

Utility[4], or satisfaction, of each retailer is the base for their decision on whether to adopt a low food waste innovation. According to Grainger et al. (2018), in this ABM retailers' utility is based on a set of parameters:

- Selling price of the product: this value can change at each step of the simulation;
- Variable and fixed costs of the adopted technology: at each step of the simulations each retailer can decide whether to change it or not;
- The set of connections with the immediate network of companies
- Different level of concern for profit;
- Different levels of concern to environmental issues, both intrinsic ("uninterested") and considered as a marketing tool;
- Level of importance given to the behaviour of direct competitors;
- Level of food waste generated internally;

On the other side, consumers are considered as homogeneous masses of defined by the typology of retailer from which they buy fresh fruit and vegetables. According to this definition, three typologies of consumers are considered in our model:

- Group A: quality oriented consumers, mostly purchase from Small retailers; those consumers have a low price sensitivity and low degree of mobility (e.g. high income urban and "foodie" consumer).
- Group B: mostly purchase from Medium Scale retailers; levels of price sensitivity and mobility are in the middle of those of the other two groups of consumers (e.g. middle class consumer, living in the province, buying from local supermarkets).
- Group C: low prices seeking consumers, mostly purchase from Large size retailers; those consumers have a high price sensitivity and a high propensity

[4] In economics, utility refers to the measurement of personal satisfaction.

to move from a retailer to another (e.g. consumers buying high quantities of food from large superstores, seeking also for discounted products).

Table 7 below summarizes the characteristics of retailers and consumers before the introduction in the market of the low food waste technology:

Table 7: retailers' and consumer' characteristics

Retailer typology	Average Sales area size (sqm)	Consumer group	Price sensitivity (country related)	Mobility
Small	<500	Group A	Low	High
Medium	501-1,000	Group B	High	Low
Large	>1,001	Group C	Medium	Medium

Concerning consumers, their utility, or satisfaction, guides their purchasing choices and is based on a set of parameters, which do not vary *inside* groups, but may change *between* groups:

- Sensitivity to the price of the commodity: this value varies between different groups of consumers and is country-based.
- The global level of information about the existence of companies which implement the food waste reduction technology. This value characterizes the whole market and can be divided in information from external sources (e.g. advertising from retailers) and information circulating among consumers (e.g. word of mouth).
- A satiation quantity, which is the same for all of the consumers, regardless of the group to which they belong. According to the ABM, satiation quantities are technology-dependent: to increase the share of utility deriving from saving money, the gross quantity of food purchased from a retailer which implements the low food waste technology will be lower than those purchased from a retailer that adopt the high food waste technology.

The Agent based Model takes also into account characteristics of retailers and consumers, based on a behavioural approach, that move them away from a perfectly rational approach to buying and selling decisions.

Retailers selling decisions are influenced by the concern for environmental issues, which can lead them to reduce their concern for profit in favour of the adoption of low food waste technologies, that have bigger costs (those costs could be eventually recovered by a future increase of selling due to the "greener" approach).

Consumers, on the other side, experience a status quo bias that influences their buying habits by limiting their propensity to change their purchasing habits. Moreover, purchasing decision are influenced by the global level of information about the existence of a low food waste technology (this is a problem of imperfect information).

Finally, consumers are considered as homogeneous groups: data on demand elasticity, transaction costs, knowledge of the existence of low food waste technologies and environmental concern are fixed within the groups. A consumer cannot pass from a group to another, but can choose to change retailer, given its preferences and selling prices.

4.4.1 What the ABM does

Given all of those assumptions, simulations conducted through the ABM evolve according to the following dynamic: at each step *t*

- Each retailer can decide to change the adopted technology, according to its utility
- Each retailer can decide whether to change selling prices: small and medium companies base their pricing decision also on the decisions made by other similar companies of their network, while large companies adapt their selling prices simultaneously
- Consumers purchasing from a company that changes technology are assigned to the same retailer
- A share of consumers becomes informed about the existence of the technology L
- A share of consumers decides to move to a different retailer, according to, their level of mobility, price sensitivity information about the existence of a low food waste technology and the selling price of the good.
- Market shares of each company are recalculated

The final results consist on the market shares of retailers that adopted the low food waste technology, both total and divided by small, medium and large retailers.

4.4.2 Baseline data for simulations

Scenarios simulated with the ABM rely on data from literature, indications extracted from interviews with experts and retailers, and on assumptions made to simulate different situations. Table 8 resumes the data from literature and from interviews, which have been used in the ABM

Table 8: baseline data for AMB simulations

Data	Italy	The Netherlands	Source
Number of retailers	17,961	4,473	IGD data
Share of small retailers	25.05%	5.12%	Elaboration based on IGD data
Share of medium retailers	70.67%	28.64%	Elaboration based on IGD data
Share of large retailers	4.28%	66.24%	Elaboration based on IGD data

Market share of small retailers	25.8%	0.85%	Elaboration based on IGD data
Market share of discounts	44.7%	18.91%	Elaboration based on IGD data
Market share of large retailers	29.5%	80.24%	Elaboration based on IGD data
National F&V waste level (%)	34%	23%	Cicatiello et al. (2017), interviews
Fixed costs of low food waste technology (%)	0%	3%	Interviews with innovators
Variable costs of low food waste technology (%)	15%	2%	Interviews with innovators
F&V waste reduction with adoption of technology (%)	16.5%	25%	Interviews with innovators
Consumers' satiation quantity with low food waste technology	83.5%	75%	Derived from food waste reduction due to technology adoption
Average price sensitivity for F&V – average national value[5]	0.268	0.299	Seale et al. (2003)
Price sensitivity for F&V - group A consumers	0.214	0.239	Elaboration on Seale et al. (2003)
Price sensitivity for F&V - group B consumers	0.268	0.299	Elaboration on Seale et al. (2003)
Price sensitivity for F&V – group C consumers	0.322	0.359	Elaboration on Seale et al. (2003)
Propensity of retailers to adopt innovations: Patents per million inhabitants[6]	1.3	1.6	Elaboration on Orbit database and Eurostat data

[5] Given the average price sensitivity (elasticity of demand) for fruit and vegetables (USDA), a variation of +- 20% has been considered for different typologies of consumers

[6] Propensity to adopt innovation by the retailers has been linked to the number of patents per million inhabitants registered by the World Intellectual Patents Organization under the code A23 (foods or foodstuffs; their treatment, not covered by other classes). We assume that that companies operating in a country with a high propensity to research will be more influenced by innovation and will be interested in adopting it

On the other side, values concerning time, information levels of consumers, mobility of consumers and intensity of network between small and medium size companies have been simulated, with the aim to evaluate their impact on innovation adoption paths in Dutch and Italian markets.

4.4.3 Assumptions and limitations

In order to simulate the innovation diffusion in Italian and Dutch markets, several assumptions have to be done, to overcome the lack of data concerning some characteristics of the agents described by the model.

The model operates in a situation of rigid demand: as reported in Seale et al. (2003), the price sensitivity for fruit and vegetables for developed countries, such as the Netherlands and Italy, is low. In this context, the propensity of consumers to change their purchasing habits is low, and this makes the adoption of innovations more difficult. This stickiness should be compensated by higher level of awareness of environmental issues and a higher level of information about the existence of technologies that prevent food waste at the retail level.

Moreover, since empirical data on food waste at the retail level are difficult to find, calibration of the ABM should rely as much as possible on interviews with experts and innovators, who can provide reliable data on food waste generated by retailers and on the expected impact of innovations on such values. Surveys on consumers' attitude are also required for a better calibration of the model.

Where data, both empirical and from interviews with experts, innovators and surveys are not available, several scenario simulations can be conducted, in order to assess different paths of innovation adoption.

The results of this work derive from different scenario simulation. As stated in previous sections, the elaboration of different scenarios has been necessary to overcome the lack of empirical data. Scenarios characteristics and source of data imputed to the ABM are described in section 5 below.

5 Scenarios and simulations results

Considering parameters and assumptions presented in section 4, six different scenarios for both Italy and the Netherlands have been designed. For each one, the average values of 50 simulations have been considered, with the aim to obtain a more accurate estimation of the results.

The simulated scenarios explore the combination of different parameters related to consumers' characteristics, market characteristics and number of iterations of the model.

Scenarios take into account two characteristics of consumers: their mobility, described as the transaction costs related to changing their purchasing habits, and their level of information about the existence of the food waste reduction technology.

Concerning market characteristics, the scenarios will consider two settings of the market: one where connections among retailers are weak (there is a low probability of connections among retailers), and another where the probability that stores are connected are higher.

Finally, simulations are conducted both in a short run and in a long run perspective, defined by the number of iterations of the model conducted for each scenario.

Results of simulations consist in the estimation of market shares of retailers adopting a food waste reduction technology, both by typology of retailer and for the whole market.

Also, a raw estimation of the possible food waste reduction at the retail level due to the shares of adoption of a single innovation is provided for each scenario. The estimation is obtained combining data on effectiveness of the innovation and on the market shares of innovation adopters. Data on food waste at national level for Italy are derived from a study conducted within the REUSE European project (Cicatiello et al. 2018), while data for the Netherlands are presented in Stenmarck et al. (2016).

Concerning Italy, in Cicatiello et al. (2018) the amount of food waste registered at the retail level is about 225,000 tons per year. While specific data on horticultural products waste are not available, the authors and the literature, especially Cicatiello et al. (2017) estimate that the share of the total food waste of retailers represented by fruit and vegetables is 34%. So, the estimated yearly quantity of wasted horticultural products for the Italian market is about 76,500 tons.

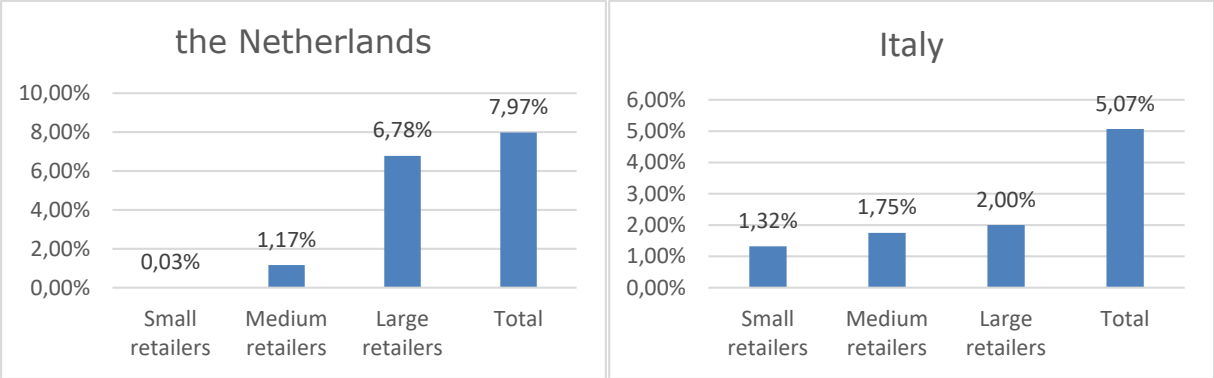
On the other side, the total food waste for the Dutch retail sectors amounts at about 18,000 tonnes, according to Stenmarck et al. (2016) Since data on fruit and vegetables waste are missing for the Netherlands, a share equal to the Italian one (34%) has been considered, since both Italy and the Netherlands are developed countries with comparable food consumption and purchasing paths. According to this assumption, the total amount of horticultural products wasted in the Netherlands each year is estimated to be about 6,120 tonnes.

Baseline Scenario

Simulated parameters		
Time (iterations)	Short Run (200)	Long Run (600)
Consumers level of information	Low	High
Consumers Mobility	Low	High
Connections among retailers	Weak	Strong

Description: This is the starting point of the simulations conducted with the Agent Based Model. In this scenario a situation where an innovation related to the reduction of food waste is introduced in a context where consumers have low levels of information about the existence of this innovation and low levels of mobility from one retailer to another. In this scenario the evolution of innovation adoption in the short term is simulated.

Results: market shares of innovation adopters



Comparative Highlights: this scenario registers the lowest market shares for innovators among all of the case considered. This is due to the low importance given to all of the aspects that could boost the adoption of innovation, such as information diffusion and connections between retailers.

According to results presented in the following table, the food waste reduction that can be achieved in this scenario is about 2% for the Netherlands, corresponding to almost 122 tons per year, and 0.8% for Italy, or 640 tons per year.

Country	Retailers F&V waste (ton)	% of adopters	F&V Waste of adopters before introduction of innovation (ton)	% of FWR due to innovation	FWR due to innovation (ton)	% of total F&V waste reduction
Italy	76,500	5.07%	3,878.6	16.5%	640.0	0.8%
Netherlands	6,120	7.97%	487.77	25%	121.9	2.0%

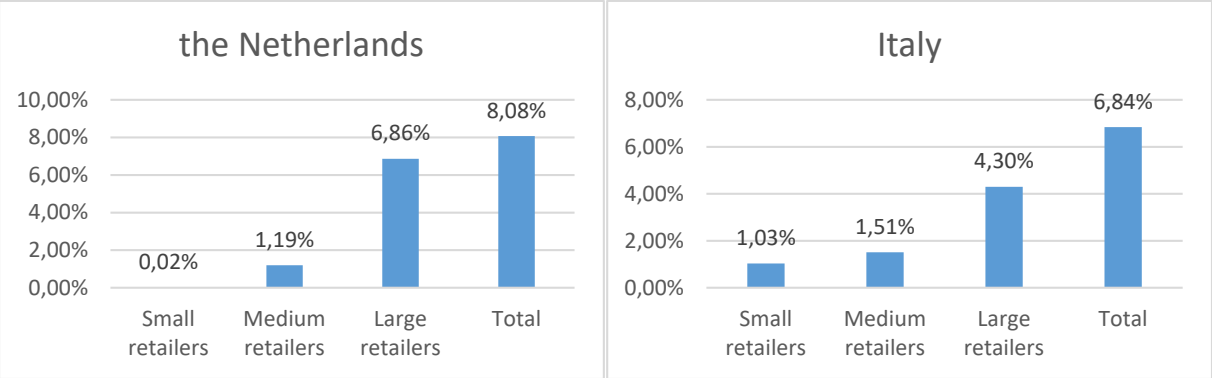
Scenario 1: Informed and dynamic consumers and isolated retailers: a short run perspective

Simulated parameters		
Time (iterations)	Short Run (200)	Long Run (600)
Consumers level of information	Low	High
Consumers Mobility	Low	High
Connections among retailers	Weak	Strong

Description: This scenario takes into account the role of information about the existence of a low food waste innovation. Consumers considered in this scenario have high levels of awareness about the existence of the food waste reduction technologies and are mobile, having low transaction cost and high probability of change the retailer where they buy food at every step of the simulation.

Aim of this simulation scenario is to evaluate the impact of behavioural aspects of consumers on innovation adoption in the short term. This is done by considering a strong concern for environmental issues and a low impact of status quo bias.

Results: market shares of innovation adopters:



Comparative Highlights: These results shows that the diffusion of information about the existence of a low food waste technology and a strong concern for environmental issues have an impact on innovation adoption especially on the Italian

market. On the other side, Dutch market registers values of innovation adoption only slightly higher than those registered for the baseline scenario.

According to results presented in the following table, the food waste reduction that can be achieved in this scenario is about 2% for the Netherlands, corresponding to 123.6 tons per year, and 1.1% for Italy, or 863.3 tons per year.

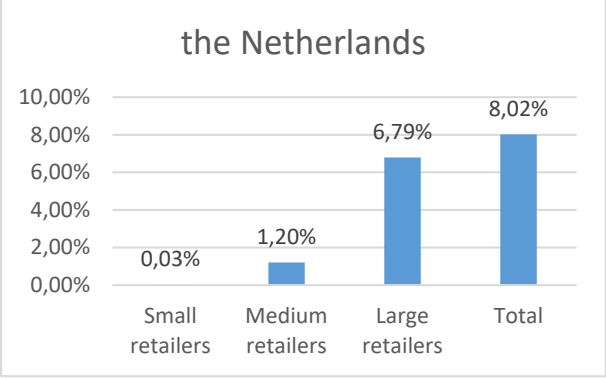
Country	Retailers F&V waste (ton)	% of adopters	F&V Waste of adopters before introduction of innovation (ton)	% of FWR due to innovation	FWR due to innovation (ton)	% of total F&V waste reduction
Italy	76,500	6.84%	5,232.6	16.5%	863.4	1.1%
Netherlands	6,120	8.08%	494.5	25.0%	123.4	2.0%

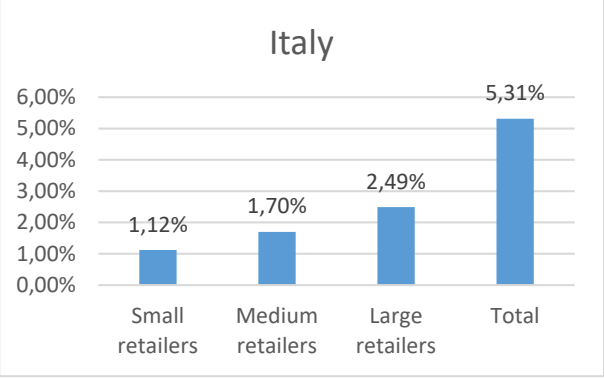
Scenario 2: Conservative consumers and isolated retailers: a long run perspective

Simulated parameters		
Time (iterations)	Short Run (200)	Long Run (600)
Consumers level of information	Low	High
Consumers Mobility	Low	High
Connections among retailers	Weak	Strong

Description: The second scenario is focused on the role of time in innovation adoption. In this case retailers are dealing with consumers who have a low level of information about the existence of innovation contrasting food waste and a lower propensity to change their buying habits. This is reflected in a lower weight of environmental concern in buying decision and in a stronger role of the status quo bias, described by higher transaction costs.

Results: market shares of innovation adopters:





Comparative highlights: in this scenario market shares are smaller than those registered in scenario 1 (short run, but high levels of information and mobility among consumers) and comparable to the values obtained in the baseline scenario. The weight of a longer period of time is not so relevant, if compared to the impact of better informed customers, on innovation adoption.

According to results presented in the following table, the food waste reduction that can be achieved in this scenario is about 2% for the Netherlands, corresponding to 122.7 tons per year, and 0.9% for Italy, or 670.3 tons per year.

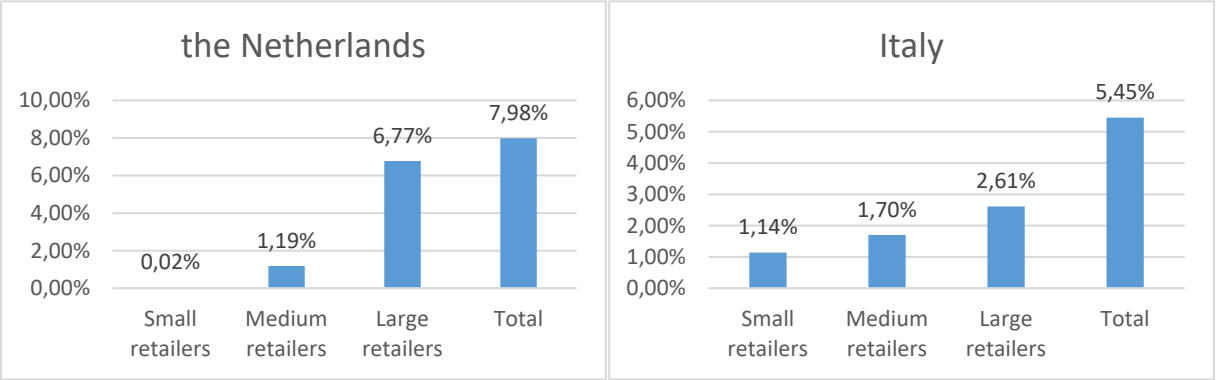
Country	Retailers F&V waste (ton)	% of adopters	F&V Waste of adopters before introduction of innovation (ton)	% of FWR due to innovation	FWR due to innovation (ton)	% of total F&V waste reduction
Italy	76,500	5.31%	4,062.2	16.5%	670.3	0.9%
Netherlands	6,120	8.02%	490.8	25.0%	122.7	2.0%

Scenario 3: Informed and dynamic consumers and isolated retailers: a long run perspective

Simulated parameters		
Time (iterations)	Short Run (200)	Long Run (600)
Consumers level of information	Low	High
Consumers Mobility	Low	High
Connections among retailers	Weak	Strong

Simulations conducted in this scenario considers the conjoint role of time and diffusion of information among consumers in adoption of innovations by retailers. In this scenario, a longer period of time is considered, and the consumers have both an increased concern for environmental issues and a higher degree of mobility, translated in low transaction costs. This scenario shows a combination of three of the four factors that have a significant role in boosting innovation adoption.

Results: market shares of innovation adopters



Comparative highlights: The combination of high values on information among consumers and of a greater amount of time considered in the simulation led to market shares comparable to those of scenario 1 for both Italy and the Netherlands. This confirms that information diffusion among consumers has a quite relevant impact on innovation adoption, regardless of the amount of time considered in the simulations.

According to results presented in the following table, the food waste reduction that can be achieved in this scenario is about 2% for the Netherlands, corresponding to 122.1 tons per year, and 0.9% for Italy, or 688 tons per year.

Country	Retailers F&V waste (ton)	% of adopters	F&V Waste of adopters before introduction of innovation (ton)	% of FWR due to innovation	FWR due to innovation (ton)	% of total F&V waste reduction
Italy	76,500	5.45%	4,169.3	16.5%	688.0	0.9%
Netherlands	6,120	7.98%	488.4	25.0%	122.1	2.0%

In the last three scenarios, the ABM takes into account the role of a strong networking among retailers as a driver to innovation adoption. As stated in section 4, the ABM assumes that retailers, in particular small and medium ones, base their price strategies also and the decision taken by their competitors present in their network (e.g. similar retailers which operates in the same territory).

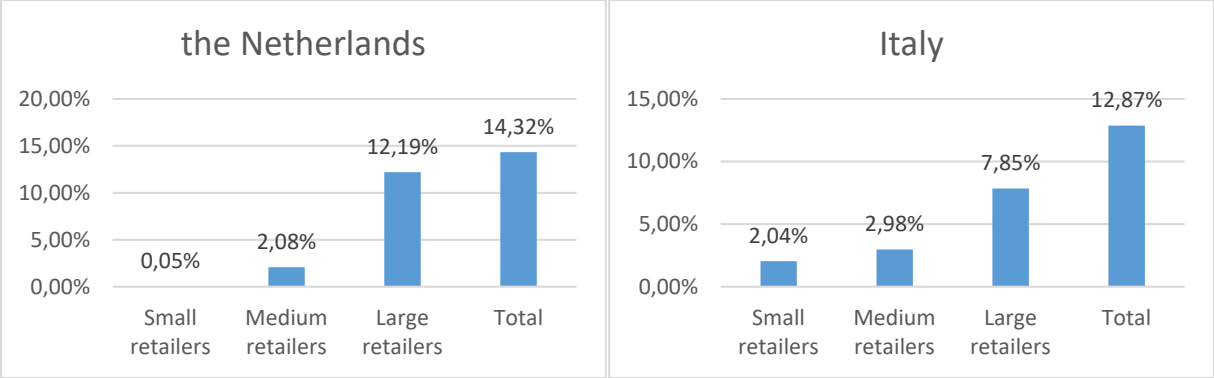
Scenario 4: Conservative consumers and interconnected retailers: a short run perspective

Simulated parameters		
Time (iterations)	Short Run (200)	Long Run (600)
Consumers level of information	Low	High
Consumers Mobility	Low	High
Connections among retailers	Weak	Strong

Aim of this simulation is to estimate only the role of strong networking between small and medium retailers, not considering high values of information diffusion, mobility of consumers and long term.

In this scenario a short amount of time is considered, while consumers have high transaction costs, because of a strong status quo bias, and have low levels of concern about environmental issues and of information about food waste reduction technologies.

Results: market shares of innovation adopters



Comparative highlights: Results from ABM simulations highlights the importance of network for innovation adoption. Both total and relatives market shares of innovation adopters are considerably higher than those of scenarios where links between companies are weaker. Market structure also influences the diffusion of innovations: large retailers registers the highest market share for innovation adopters, but differences between large and smaller retailers are more evident for the Netherlands, while in Italy adoption of innovations is more shared among retailers of any size.

According to results presented in the following table, the food waste reduction that can be achieved in this scenario is about 3.6% for the Netherlands, corresponding to 219.1 tons per year, and 2.1% for Italy, or 1,624.5 tons per year.

Country	Retailers F&V waste (ton)	% of adopters	F&V Waste of adopters before introduction of innovation (ton)	% of FWR due to innovation	FWR due to innovation (ton)	% of total F&V waste reduction
Italy	76,500	12.87%	9,845.6	16.5%	1,624.5	2.1%
Netherlands	6,120	14.32%	876.4	25.0%	219.1	3.6%

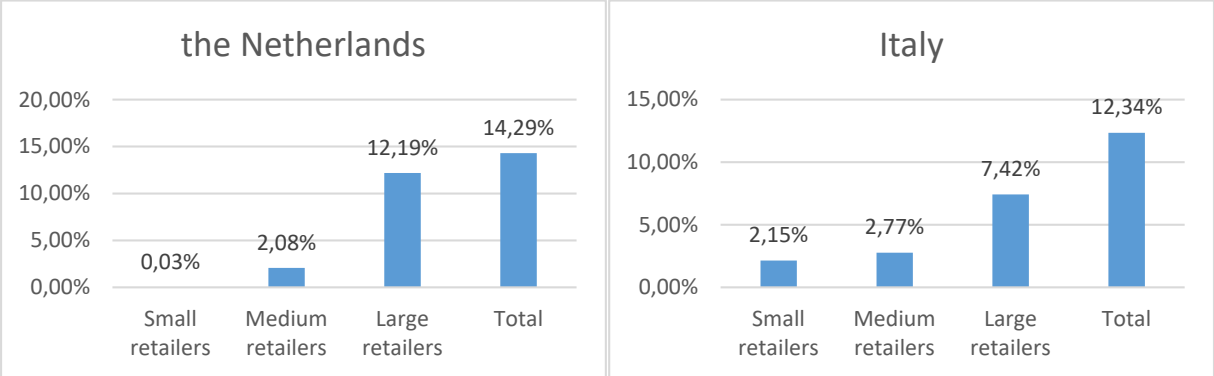
Scenario 5: Informed and dynamic consumers and interconnected retailers: a short run perspective

Simulated parameters		
Time (iterations)	Short Run (200)	Long Run (600)
Consumers level of information	Low	High
Consumers Mobility	Low	High
Connections among retailers	Weak	Strong

Description: In this scenario the role of information and mobility of consumers is matched with the strength of network among retailers in order to assess the adoption of innovations in the grocery retail market.

Given those assumptions, this scenario simulates the evolution of Dutch and Italian markets on the short run, where consumers are quite aware of the existence of a food waste reduction technology, have stronger concerns for environmental issues and a high degree of mobility.

Results: market shares of innovation adopters



Comparative highlights: Increasing weight of information diffusion have different impact on the markets of Italy and the Netherlands.

While results for the Dutch case are comparable with those of scenario 4, the Italian scenario presents some differences with the previous simulations.

Increase of information diffusion in the Italian market led to higher market shares for small and large scale retailers adopting the food waste reduction innovation, while the market shares of medium are lower than those registered for previous situation. Probably this is due to the more aggressive pricing policy of large scale retailers, which charge selling prices lower than the other retailers, "draining" customers from their smaller competitors.

According to results presented in the following table, the food waste reduction that can be achieved in this scenario is about 3.6% for the Netherlands, corresponding to 218.6 tons per year, and 2% for Italy, or 1,557.6 tons per year.

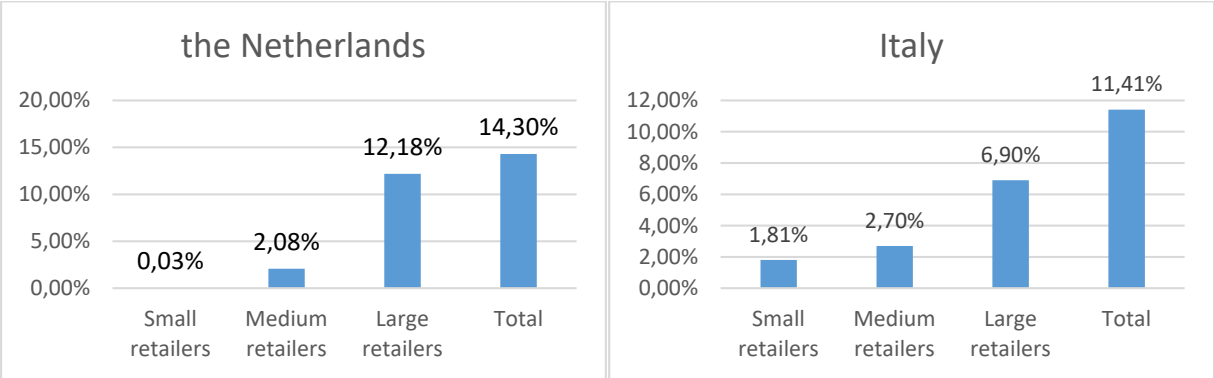
Country	Retailers F&V waste	% of adopters	F&V Waste of adopters before introduction of innovation	% of FWR due to innovation	FWR due to innovation	% of total F&V waste reduction
Italy	76,500	12.34%	9440,1	16,5%	1557,6	2.0%
Netherlands	6,120	14.29%	874,5	25,0%	218,6	3.6%

Scenario 6: Informed and dynamic consumers and interconnected retailers: a long run perspective

Simulated parameters		
Time (iterations)	Short Run (200)	Long Run (600)
Consumers level of information	Low	High
Consumers Mobility	Low	High
Connections among retailers	Weak	Strong

Description: In this scenario, assumption from scenario 5 and 6 are matched with a larger amount of time taken into account during ABM simulations. Here, consumers are well informed about the existence of food waste reduction innovations, have strong concern on environmental issues and are less sticky to their consumption habits, having high levels of mobility. Moreover, linkages between retailers, especially among small and medium companies are strong. Finally, a greater amount of time is considered for the simulation conducted for this scenario.

Results: market shares of innovation adopters



Comparative highlights: the combination of high levels of information among consumers with a high level of concern on environmental issues, strong networks between companies and long period leads to the highest levels of innovation adoption. In this scenario, the Netherlands registers market shares of innovation adopters, both total and related to retailers of different share, greater than those registered in all of the other scenarios. Italy, on the other side, registers values comparable to those obtained for scenario 5 and 6.

According to results presented in the following table, the food waste reduction that can be achieved in this scenario is about 3.6% for the Netherlands, corresponding to 218.8 tons per year, and 1.9% for Italy, or 1,440.2 tons per year.

Country	Retailers F&V waste (ton)	% of adopters	F&V Waste of adopters before introduction of innovation (ton)	% of FWR due to innovation	FWR due to innovation (ton)	% of total F&V waste reduction
Italy	76,500	11.41%	8.728.7	16.5%	1.440.2	1.9%
Netherlands	6,120	14.30%	875.2	25.0%	218.8	3.6%

6 Conclusions and further applications

Lessons learnt from REFRESH retail scenarios

Results of the simulations implemented through the Agent Based Models concerning the Italian and the Dutch fresh horticultural sector show that innovation adoption by retailers is a complex process, that is influenced by a number of factors, which are not limited to purely economic factors.

The driver which seems to have the greater influence on retailers' decision whether to adopt food waste reduction innovations or not is the strength of networks among retailers, in particular concerning small and medium companies. The role of networks among retailers is relevant both for Italy and the Netherlands, despite the differences between their grocery market structures. The Dutch market is characterized by a limited number of small retailers and is dominated by few large retail chains, while in Italy the share of small and medium companies is relatively higher.

Moreover, the prominence of those factors is consistent especially for sectors such as the fresh fruit and vegetables, where consumers are characterized by a limited sensitivity to price changes and a limited propensity to modify their purchasing habits.

A second factor with some influence on the diffusion of innovation is the level of awareness of consumers about the existence of a food waste reduction technology. As expected the combined effect of high levels of awareness among consumers and the presence of strong networks among retailers leads to a wider adoption of food waste reduction technologies. In particular, markets with high density of connections among retailers and high levels of information among consumers present high rates of adoption of technologies that generates low levels of food waste.

Another relevant lesson is represented by the estimations of total food waste reduction conducted for each scenario in section 5. As reported in the previous section, the contribution to food waste reduction from each single innovation is not so high in terms of percentage, while having a quite valuable impact in terms of absolute quantities. More specifically, the food waste reduction at the retail level due to the considered innovations (active packaging for Italy and misting technology for the Netherlands) goes from 2% to 3.6% for the Dutch case (equal to a range of about 122-218.8 tons per year) and from 0.8% to 2.1% in the Italian case (corresponding to a range of about 688-1,610 tons per year).

But, if a single innovation cannot resolve the problem of food waste of retailers by itself, because of its limited impact in term of quantity reduction, a combination of different, and complementary, innovations, which tackle specific aspects of the food waste of retailers could significantly contribute to the overall reduction of food waste at the retail level and all along the FSC.

What role for agreements and networks?

Results from the ABM simulations highlights a consistent difference between scenarios where connections between retailers are weak and scenarios where companies are more interconnected. As demonstrated in section 5, in a market where retailers are connected, the adoption of innovations is considerably wider, compared to scenarios where connections among retailers are weak. This is especially

true for small and medium retailers, which base a relevant part of their market strategies on their competitors' behavior.
Those results point to agreements and other collaborative forms as a relevant policy instrument for fostering the adoption of food waste reduction innovations.

What the REFRESH retail ABM can offer

The REFRESH ABM can support the identification of the key factors that influence the adoption and diffusion of innovation at the retail level allowing a better understanding of the overall complexity. This tool can be used by researchers and policy makers to assess the diffusion and the impact of new food waste reduction technologies, such as by innovators to better estimate the impact of their products or services.

Simulation scenarios can focus on specific parameters to isolate and evaluate specific factors, such as time, role of information and awareness among consumers concerning the existence of food waste reduction innovations and their characteristics, role of economic factors (e.g. price levels, price sensitivity, concern for profit) and impact of behavioral factors, such as the concern for environmental issues linked to food waste reduction.

Current limitation and future opportunities

This study is a first attempt to model the process of adoption, by retailers, of food waste reducing innovations, by taking into account factors from behavioral economics. The case studies described in this study have an illustrative character to show the possible opportunities to model food waste reduction and explain factors affecting the decision to adopt a certain innovation. A general limitation resides in the characteristics of the innovation addressing food waste reduction. In most of the cases these innovations are targeting specific products within a certain group: i.e. the Italian innovation (active *packaging*) is targeting nectarines within horticultural produce. To be more effective innovation should be implemented in a systemic manner identifying a comprehensive strategy to target a wide range of products.

Moreover, the current model is suffering from limited data availability. A more comprehensive dataset, including, for example, more information about the diffusion of new technologies among retailers and about their approach to food waste reduction innovation would allow to release some of the assumptions ensuring a better fit of the model with real word situations and therefore an extension of its explanatory capacity.

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8 MatLab codes

The MatLab and R codes used to run the integrated ABM-BN model can be provided upon request, addressable to any of the Authors of the report through the REFRESH website.