

Exploring the Potential of Business Models for Sustainability and Big Data for Food Waste Reduction

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Abstract

Because the volume of food waste is increasing, actions are required to mitigate the environmental and social impact of food waste generation. This paper investigates the business models of 41 selected startups (technology and service providers) to capture how companies avoid food waste or use food waste as a resource. The case study analysis, based on secondary sources, shows that some startup business models leverage Big Data Analytics (BDA) to avoid food waste by optimizing an existing linear supply chain, while other business models create value out of food waste by leveraging a circular food supply chain. We found that the latter business models are not fully exploiting the potential of BDA. Based on our findings, we derive three propositions and one corollary. Whereas BDA seems a necessary requirement for business models that are focused on optimizing a linear supply chain, it appears optional for business models closing the supply chain loop. The propositions also discuss the timing when startups should start developing BDA capabilities depending on the business model type.

Keywords: food waste reduction, sustainable business model, big data

1. Introduction

Food waste has reached unprecedentedly high levels. Every year, globally, more than 1.3 thousands of million tons of food ends up being wasted (Gustavsson et al., 2011). From a social viewpoint, it is unfair to waste food, while many regions still suffer from famine and malnutrition. According to the Food and Agriculture Organization of the United Nations (FAO), in 2020, between 720 and 811 million people have faced hunger (FAO, 2021). From environmental and economic standpoints, food waste entails production and logistics activities that do not result in product consumption. In 2014, FAO estimated that the societal costs of food wastage were about USD 2.6 trillion, of which USD 700 billion are connected to the environmental impacts, and USD 1 trillion are due to economic losses because of wasted and lost production (FAO, 2014). Given its relevance, some institutions call society and companies for reducing food waste. For instance, the United Nations included the reduction of food waste along supply chains as a target (target 12.3) in their Sustainable Development Goals (SDG) framework. In addition, consumers are increasingly preferring products that contribute to food waste reduction (Altintzoglou et al., 2021), thus incentivizing companies to take measures against the causes of food waste.

Positive actions that aim to deal effectively with ‘surplus food’ can be put in place (Garrone et al., 2014). For example, Circular Economy (CE) considers ‘waste as a resource’ and represents an approach to solve the food waste challenge (Redlingshöfer et al., 2020). In this regard, the food waste hierarchy (FWH) provides a comprehensive framework that prioritizes possible actions, which range from prevention of surplus food to the extraction of a new value in the form of new edible or non-edible products (Cristóbal et al., 2018).

Prevention has top priority in FWHs because it eliminates food waste by addressing its main root causes. Food waste prevention requires know-how (e.g., technological capabilities) that the actors in the core food supply chain may not possess. Therefore, collaborations with technology providers can be of paramount importance (Ciccullo et al., 2021). Alternatives at lower layers of FWH such as *Redistribution of surplus food*, *Re-use for human consumption*, *Recycling: Re-use for animal feed*, *Re-use for other industries/ Composting*, and *Recovery: Waste-to-energy* imply the necessity of collaborating with third sector organizations (e.g., food banks) and companies in other industries (Garrone et al., 2014). This collaboration drives relevant changes in current

value creation, hence the importance to rethink business models by e.g., leveraging circular systems in a collaborative way (Farooque et al., 2019). Thus, food waste prevention calls for changes that go beyond the supply chain to embrace business model innovation (Mourad, 2016).

The literature that provides empirical evidence on good practices for reducing food waste is still limited. So far, research has mainly focused on retail and consumer's viewpoint (Principato et al., 2019), while looking at the food waste problem either from a supply chain or business model lens. The food supply chain depicts the involved actors and flows, whereas business models denote the logic of the business created around food waste. In this work, we propose a research framework that includes both perspectives by considering different business models along the food supply chain. Business models for sustainability seem to be of special relevance for our investigation. Therefore, by starting from a generic food supply chain, we pose the first research question:

1) What are the innovative business models for sustainability that have been created to cope with food waste at each stage of the supply chain?

To answer this question, we analyze the academic and practitioner literature to capture new business models along the food supply chain with the objective of discovering new patterns of doing business.

This initial research question led to discovering the potential of Big Data (BD) and Big Data Analytics (BDA) in driving new business models related to food waste. We understand BD as large datasets (*volume*), generated with high frequency (*velocity*), that exceed the handling and storage capability of traditional data management systems, and that can be composed by data with various data formats (*variety*) (Hofmann, 2017). The application of advanced analytics to BD is called BDA (Xu et al., 2021; Arunachalam et al., 2018; Wang et al., 2016). Despite BDA has been identified an important technological solution to support the supply chain management process, literature that investigates the enabler role of BD for the creation of business models for sustainability, is still at its infancy (Farooque et al., 2019). Hence, the second complementary research question:

2) How could the BD generated along the supply chain be useful for food waste management?

By relying on secondary data, we generate a case study database containing 41 startups. Our analysis shows that these startups use two basic types of business models for sustainability: “optimize material efficiency” models, which aim to reduce the level of food waste, and “closing the loop” models, which create value from waste. These business models are classified into four clusters, depending on their current BDA capabilities and the unexploited potential in BDA that startups can leverage to even reduce further food waste in the future.

The paper is structured as follows. Section 2 presents the research framework. Section 3 introduces the research methodology, whereas section 4 focuses on findings. Section 5 discusses the results and formulates propositions. Finally, section 6 summarizes the main insights and identifies directions for future research.

2. Research Framework

The research framework in Figure 1 shows that each supply chain stage, be it the farmers, processing companies, retailers, or end consumers is a potential contributor to waste generation. Hence, all these stages should be concerned with the causes of food waste. The framework also considers business models for sustainability. Actors along the supply chain can leverage business models for sustainability to better mitigate the causes of food waste generation. For example, companies may involve value-adding systems outside their core food supply chains. Furthermore, BD and BDA can provide solutions that address the causes of food waste, support the core food supply chain, and lead to new business models for sustainability.

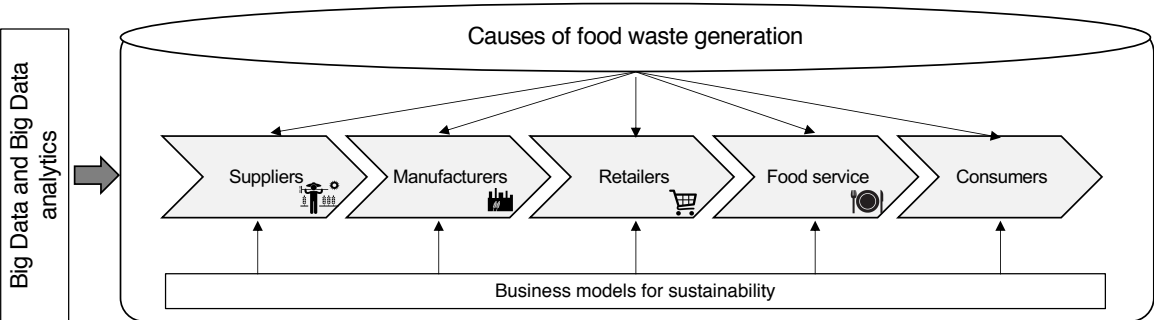


Figure 1 - Research Framework

2.1. Stages in the core food supply chain

Farmers supply agricultural and animal raw materials in the food supply chain. There are two types of food products: fresh and processed food with different implications for the supply chain. For fresh agricultural products, farming activities are conducted in the initial stage, then handling, sorting, storing, and packing activities take place in packing houses (Mena et al., 2011, Mena et al., 2014, Papargyropoulou et al., 2014). Processed food supply chains (Van der Vorst et al., 2001) use the inputs from agricultural and animal breeding activities to produce consumable food products with higher added value (Mena et al., 2011). Processed food includes additional manufacturing activities that imply physical (e.g., cleaning, cutting grinding, etc.) or chemical transformation (e.g., cooking, frying, drying, etc.) (Monteiro et al., 2010; Papargyropoulou et al., 2014). For the downstream stage, food is distributed to the final consumers through wholesalers and retailers (Aazami and Saidi-Mehrabad, 2021), whereas consumption stages are represented by food service (i.e., Ho.Re.Ca segment, but also collective catering) and consumers' households (Mena et al, 2011, Özbük and Coşkun, 2020).

2.2 Causes of food waste generation

Following Mena et al. (2014) and Mena et al. (2011), the root causes of food waste can be classified into *supply and demand-related trends* (e.g., shifts in demand due to the willingness of customers to buy products with no preservatives), and factors related to *quality and process control* (e.g., planning, forecasting, promotions management, inventory management). Table 1 provides a detailed list of food waste root causes at the different supply chain stages. Upstream the food supply chain, poor planning accuracy due to challenges in demand forecasting and planning at multiple supply chain stages can cause surplus food (e.g., Richter and Bokelmann, 2016), whereas lack of proper storage and transportation infrastructures (e.g., Ozbük and Coskun, 2019a) are main sources of food waste. In the downstream supply chain, consumer's behavior such as product selection based on high aesthetic standards (e.g., Göbel et al., 2015; Teller et al., 2018) and consumption habits related to at home and out of home routines (e.g., Secondi et al., 2019) can be conducive to food waste.

It is true that each actor can contribute to food waste and that waste should be reduced at all stages of the supply chain, but the upstream-downstream interface between manufacturer and retailer is of paramount importance. At this interface, products have reached their highest level of value added (Mena, 2011, Eriksson et al, 2017). Thus, from

an economic viewpoint, waste, at this stage, induces the highest value loss, as compared to upstream supply chain stages.

Table 1 – Causes of food waste along the food supply chain

CAUSES OF FOOD WASTE IN THE FSC							
		Upstream		Upstream-Downstream Interface	Downstream		
		Supplier	Manufacturer	Manufacturer-Retailer interface	Retailer/Wholesaler	Food service	Consumer household
SUPPLY AND DEMAND MANAGEMENT	Planning, forecast and information flow	Low forecast accuracy (2,3,4)	Low forecast accuracy (2,3,4) balancing demand and supply (2), sales variability (2)	Low forecast accuracy (1, 2,3,4) planning errors combined with short shelf-life ¹ , poor cold chain management (1,2) lack of information sharing (Bullwhip effect) (1,2,3) Take-Back Agreements (TBAs) (1,3,4)	Low forecast accuracy (2,3,4), unsophisticated, long SC design, and demand seasonality (2) , variability in ordering (2,6) lack of communication (marketing side) (3), width and depth of product range in store (2,6)	Low forecast accuracy (3,4) poor demand planning (3,4) lack of a menu planning phase (3)	
	Promotion management		Promotion-driven waste (food and packaging) (2)	Irregular demand due to demand (1,6) and inefficient information sharing (1), Risk of cannibalization (1)	Demand-driven rather than supply-driven promotions (2), too many products allocated to stores during promotions (6), retailers' inflexibility (2)		Customer education on waste management (3)
	Availability & Inventory		Wrong storage temperature (3), overproduction (2,4), too many stocks (3,4)	Poor stock rotation on shelves (1), inflated orders to make shelves look full (1,4)	Stock management (2,3,4) and stock rotation policy (1,3)		Eating habits, behaviour of customers that throw away products still edible (3)
QUALITY AND PROCESS CONTROL	Product specifications	Quality of products during and post harvesting ²	Different interpretations of quality of vegetables among different suppliers (2), product deterioration (2), retailer specifications (1,3,4,5), legislations (e.g., meat), risk of contamination (2,5)	Rejected deliveries due to unmet quality and service level expectations and requirements (1,3,4,5), differences in appearance (e.g., shape and size) (1,3,4,5), product quality issues (mold, diseases) (1,2,4,5)	Consumers' expectations and education (3,5,6), strict/unmet product quality standards, as: shape, size, appearance, etc. (1,3,4,5)	Portion size (3), menu complexity and variety (3)	Products' expiry date (4)
	Process control	Poor harvest management ² , destructive quality control ² , weather variability ² , absence of waste handling strategy ^{1,3}	Technical problems at the processing stage (3,5), temperature control (2,3), destructive quality control (2), absence of waste handling strategy (1,3)	Product damage due to poor handling, particularly in store (e.g., training problem) (1,3,5) failures in refrigeration (1, 3) , seasonality of supply (1)	Temperature management (during transportation and storage) (2,5), management in store (display and back-store) (2,5,6), poor handling in store (by consumers and staff) (2,5,6), quality control (2), weather changes (2), absence of waste handling strategy (1,3)	Absence of food waste handling strategy (1,3) age of customers (3)	Customers' lack of tolerance to the appearance and quality of fresh produce (3,4,5,6)
	Shelf life mgmt			Out of shelf-life product (1,5), short shelf-life products constraints (1,5), insufficient shelf space available (1,3,6)	Expired products or too close to the best-before-date (4,5,6)		
	Packaging and labelling		Damage during packaging stage (2,3) wrong labelling (2,3) changeovers (short product runs) (2), damage in storage or transit (2), size of secondary packaging (6)	Packaging and labelling mistakes (1,2,3)	Impossibility of repacking if one item becomes diseased or out of specification, leading to throwing away the whole pack (2)		
OVERALL		Demographic and socio-cultural factors (3,5), Political factors (3), Food scandals (4)					

Legend: (1) (Mena et al., 2011), (2) (Mena et al., 2014), (3) (Ozbük and Coskun, 2019), (4) (Richter and Bokelmann, 2016) (5) (Göbel et al., 2015), (6) (Teller et al., 2018)

2.3 Business models for sustainability

Business models have been broadly discussed in academia and practice. There are two types of business model understandings: (1) activity- and (2) value-based views (Abdelkafi and Täuscher, 2016). The activity-based view considers the purposeful weaving together of the firm's and its partner's activities at the heart of business model design (Zott and Amit, 2010). Abdelkafi and Pero (2018) use the activity-based understanding to show the impacts of supply chain changes on business models. In the value-based perspective, a business model is defined as the way organizations create, deliver, communicate, and capture value out of a value proposition (Abdelkafi et al., 2013). The value-based perspective has been used frequently in the context of business models for sustainability.

Being a subset of the general concept of business models, business models for sustainability have been defined in different ways in the academic literature. Several studies attempt to conceptualize business models for sustainability (e.g., Abdelkafi and Täuscher, 2016). In the conceptualization of Abdelkafi and Täuscher (2016), a business model for sustainability enables the firm to reinforce the mutual interdependencies between the value created for its customers, the natural environment and the value captured by itself. Hence, the more products and services (value proposition) the company sells, the more it accumulates benefits for the environment and society, and the more value it generates for itself and partners. For example, Bettervest, a Germany-based crowdfunding platform, is a case in point. It collects relatively small amounts of money from many investors to fund energy efficiency projects at organizations such as commercial firms. Investors get paid a percentage of the energy savings achieved through the implemented projects. Thus, as Bettervest facilitates the funding of more energy efficiency projects, it captures more value for itself and creates more value for its customers (in terms of monetary compensation for investors and commercial firms that carry out the energy efficiency projects) as well as for the natural environment (in terms of reducing environmental harm) (Abdelkafi and Täuscher, 2016). Bocken et al. (2014) built upon existing knowledge on business models for sustainability to elaborate a framework that consists of different business model patterns. Bocken et al. (2014)

mapped eight different business model archetypes classified along three dimensions: technological, social, and organizational. Technological archetypes include business models of firms that ‘do more with fewer resources’ (resource efficiency) or substitute renewable resources and processes that mimic the nature for existing inputs and processes. Social archetypes are implemented by firms that leverage socio-cultural changes. These business models include (i) the adoption of a stewardship role with suppliers, while implementing practices that increase social inclusion and value creation capabilities and (ii) product service systems, which imply a change in the consumption behavior. Organizational archetypes leverage a change in the way, in which a company interacts with other stakeholders such as the environment, society, and other similar companies to scale up solutions in a shared ecosystem. Despite its relevance, this initial framework was criticized in the academic literature. Lüdeke-Freund et al. (2018) pointed out that the ‘social’ group in Bocken et al. (2014) capitalizes on behavioral changes only with respect to customers and suppliers, but do not consider other stakeholders towards which social value creation can be of paramount importance. Based on these premises, Lüdeke-Freund et al. (2018) integrate the archetypes proposed by Bocken et al. (2014) with additional patterns (for a total of 11) including some aspects of the social dimensions.

Regarding the business models for the circular economy (CE), Bocken et al. (2014) refer to the archetype ‘create value from waste’ among the technological ones, stressing mostly the environmental implications. Pieroni et al. (2019) questioned the sustainability of the CE business models. In their view, not all CE innovations imply sustainability since they can generate negative secondary effects. In addition, not all sustainability-oriented business models necessarily include circular principles. Whereas the social dimension is not pursued directly by the CE business model, it is an important component in the business models for sustainability. For the CE business models, resource efficiency, resource longevity/effectiveness, and economic growth are the main drivers, but not the social dimension.

From the environmental side, business models for CE seem, therefore, to be endowed with a reinforcing loop-based engine that generates increased monetary and environmental values, as more consumption of the value proposition takes place. The same is also true for those business models that aim to exploit food waste to generate value. These business models exist, just because of the existence of food waste. They ensure the subsequent usage of food waste generated along a supply chain. The more food waste is produced, the more value is generated, ideally for the company, environment,

and stakeholders. These business models, however, should be leveraged when food waste is inevitable. On the side of potential food waste producers, however, business models should be endowed with the capability of preventing completely the generation of food waste. In this way, it becomes unnecessary to create subsequent business models that make use of that waste, since it simply does not exist.

2.4 Big data and big data analytics

In line with what stated above, the term *Big Data* (BD) indicates large datasets of structured or unstructured data that exceed the management capacity of traditional data management systems. By applying advanced analytics to big data (*Big Data Analytics - BDA*), information and insights can be extracted to support decision making (Xu et al., 2021, Arunachalam et al., 2018, Wang et al., 2016).

Literature contends that BDA can be leveraged to increase the sustainability performance of supply chains (Dubey et al., 2018, Liu et al., 2020). Sharma et al. (2020) show that (big) data collected along all the stages of supply chains in agriculture—from pre-production to distribution—and analyzed by means of machine learning techniques, can improve supply chain performance and environmental sustainability. For instance, accurate weather forecasts can enable an effective management of water resources (Terêncio et al., 2017). Moreover, the possibility to extract valuable insights from BD may support supply chain visibility and enable collaboration for sustainability (Dubey et al., 2018). In general, the environmental sustainability of supply chains can be improved by using BDA to predict the impact of supply chain-related decisions on the environment (Zhao et al., 2017).

The survey by Dubey et al. (2018) shows that BDA application is positively associated with perceived social performance. Mani et al. (2017) highlight how BDA can be used to predict and manage social risks such as workforce safety.

While a fair body of literature deals with how BDA can improve Supply Chain sustainability, there is only limited knowledge on the relationships between BDA and business models for sustainability. In particular, taking the CE perspective, Jabbour et al. (2019) show that the characteristics of BD can enable the implementation of circular business models described through the ReSolve model (Ellen MacArthur Foundation, 2015). Despite its relevance, the framework proposed is rather theoretical. As supported by the literature reviews in de Sousa Jabbour et al. (2018) and Rosa et al. (2020), there is

a need to investigate empirically how industry 4.0 technologies, among others BDA, can support CE and how BDA can be practically used to set up circular business models.

3. Research methodology

To answer our research questions, while providing in-depth and empirically-based insights, we develop multiple case studies based on secondary sources. The sample of case studies consists of startups. Startups are '*small firms, recently founded and that have a relatively small market share*' (Hockerts and Wüstenhagen, 2010, p. 483). They are less complex than established companies in organizational and governance structure, supply chain configuration, and other business model aspects. Startups are particularly suitable for our study due to their innovative business models. Despite their relatively small market share, these companies are all "born sustainable", and their aim is to trigger an environmental or a societal change (Hockerts and Wüstenhagen, 2010). Indeed, they are more likely to develop innovative approaches compared to large, consolidated companies (Hockerts and Wüstenhagen, 2010). Moreover, they have incorporated sustainability, in particular food waste reduction, as a core activity of their business models since their inception. Consequently, startups represent adequate units of analysis to investigate innovative business models for sustainability and identify novel approaches to using BDA in food waste management.

3.1 Data collection

Data collection started with the identification of the sample of companies to investigate. It is organized in two phases: screening and consolidation.

The *screening phase* consists of two parallel steps: i) online research, and ii) a short questionnaire that involves a pool of selected experts. The initial screening aimed at identifying the most relevant startups with innovative and sustainable solutions for food waste management. In the web-based research, we set "*food waste startups*" as key search terms (Date of search: February 22, 2021) in Google and analyzed the websites of the first 10 links, leading to a total of 27 startups. To get further support that the final sample of startups covers a good number of promising and well-known startups, four experts in the fields of food waste prevention and reduction, circular economy, and food sustainability innovation, with extensive knowledge on innovative and sustainable entrepreneurial initiatives in the food industry, were identified. The number of experts

involved in this screening phase is consistent with the small pool of experts adopted in similar studies that rely on secondary sources (e.g., Linz, 2012). All four experts were asked to participate in an open-ended questionnaire and to list the names of a minimum of five innovative startups and a maximum of 10, which can be associated with food waste reduction without any ad-hoc online research. Their replies partly confirmed and partly enriched our initial list with additional 30 cases identified.

Moving to the *consolidation phase*, we first exclude repetitions from all 57 identified cases. Then, to obtain the final set of startups to be included in our sample, we apply the following inclusion/exclusion criteria:

- i) The selected startups must be food waste specific.
- ii) They should be currently active, in other words those out of business are excluded.
- iii) They should have received funding from investors, as a proxy for quality business models.
- iv) They can be analyzed at a good level of depth because a good amount of information on the business model can be retrieved online and through secondary sources.

This process led to 41 different startups. Table 4 includes an overview of the sample.

3.2. Data analysis and coding

Relevant data on the companies in our final sample is extracted from different secondary sources: i) websites that provide a list of “best” or more promising startups in the area of food waste reduction and details on the essence of their business models (e.g.: <https://www.recyclingstartups.org/top/food-recycling/>), and ii) the startups’ own webpages as well as other publicly available resources such as web articles and presentations. The data collected is coded according to deductive and inductive coding approaches. We use deductive coding to assign each selected startup to: i) a specific food supply chain stage, ii) to a particular layer in the food waste hierarchy, and iii) to one or more business model archetypes for sustainability. We also use the inductive coding approach, in which codes emerge out of the data collected. Hence, these codes are not necessarily supported by an existing framework. The inductive coding approach resulted in the identification of BDA capabilities as an important element in the business model for sustainability used by the startups. The data analysis enables us to distinguish different

types of capabilities in exploiting BDA for food waste reduction. In the following, we provide the details of our deductive and inductive coding approaches.

The *deductive coding* approach relies on three frameworks. First, startups are allocated to supply chain stages by drawing on the research framework introduced above. Second, the assignment to the corresponding layer of the food waste hierarchy is based on Papargyropoulou et al. (2014) and Mourad et al. (2016). The main sources of information used to collect useful information are: i) the description of the company's main activities in the websites that report lists or rankings of startups, and ii) the "about us" section of the startups' own websites. Third, every startup is assigned to one or more business model archetypes according to Bocken et al. (2014). We identify statements and quotations from the startups' websites or available company's presentations, which we assign to "value proposition", "value creation" and "value capture", the main elements of the business model. For the development of the codes book, we create codes that are specific to the food industry. For example, the archetype "encourage sufficiency" in Bocken et al. (2014) is related to the value proposition and creation elements and aims to avoid over-consumption. It is equivalent to "demand management to match supply with demand", and "educate costumers to reduce households' food waste". The archetype "repurpose for society and environment" is connected to the value capture elements and means in our context "to devote a share of the unitary margin to create social value" or "to prioritize social and environmental value capture over economic value capture".

The *inductive coding* approach is used for the analysis of the BDA's role in different business models for sustainability. This coding approach has led to two main dimensions according to which companies can be classified: i) the current level of BDA exploitation, which signals the BDA capabilities of the startup, and the future potential of BDA in improving the level of food waste reduction. The current level of BDA exploitation depends on the number of steps in the data value chain and the related capabilities developed. According to Miller and Mork (2013), the data value chain consists of three main phases: data discovery, data integration, and data exploitation. Data discovery is composed of collect & annotate, prepare, and organize, whereas data exploitation consists of analyze, visualize, and make decisions. Data integration is not divided into further sub-activities. The Current BDA exploitation level of startups in the sample is evaluated high if the company already analyzes, visualizes data, and make decisions based on BD.

Exploitation is, however, low when the company does only data discovery and integration.

BDA's future potential in reducing food waste is related to FWH. This potential depends on whether the startup can leverage its BDA capabilities to support its current FHW level or even achieve higher FWH levels.

Both deductive and inductive coding processes were performed through joint discussions among the authors, thus achieving convergence.

4. Findings

4.1. Solutions to food waste along the FSC and the FWH

The sample of startups for food waste prevention and management can be linked to one or more layers of the food waste hierarchy (FWH) and, at the same time, each layer can be addressed by more than one startup. Table 2 clusters the selected startups according to two dimensions: the layer(s) in the food waste hierarchy and the stage of the supply chain where food waste is generated. Our sample covers almost all intersections between FSC and FWH. Along the FSC, retail/wholesale is the stage exhibiting most cases (with a total of 21 startups). Fewer cases are found in the stage of household consumption, probably because surplus food at this stage is generally in the form of cooked or semi-cooked food and it depends on the individual households. Geographical dispersion of households makes redistribution and reuse hard to be implemented.

Food supply chain					
Layers in the food waste hierarchy	Upstream		Downstream		
	Supplier	Manufacturer	Retailer/Wholesaler	Food service	Consumers
“Strong” prevention / “Weak” prevention	Apeel science Fresh4cast	Spoiler Alert; Fresh4cast	Spoiler alert; Apeel Sciences; Matsmart; Shelf Engine; Insignia Technologies; Cronogard; Wasteless; IUV; Packtin	Winnow; Do Eat; Easilys	Apeel science
Redistribution	'Food Cloud; Imperfect Foods; Bella Dentro; Babaco Market; Bring the food; Full Harvest	Food Cloud; Goodr; Bring the food	Too Good To Go; Food Cloud; Olio; Phenix; Karma; Bring the food.	Too Good To Go; Olio; Phenix; Copia	Olio
Re-use for human consumption	WTRMLN WTR; Barnana; Rubies in the Rubble; Imperfect Foods; Bella Dentro	Renewal Mill; Regrained; Bio-bean; Mialgae	Peelpioneers; Biova	Bio-bean; Peelpioneers; Riseproducts	
Recycling for animal feed Recycling for other industries/ Composting	Phenix; Ricehouse	Renewal Mill; Regrained Bio-bean Mialgae	Phenix; Peelpioneers; Entocycle	Phenix; Peelpioneers; Entocycle	
Recovery: Waste-to-energy	Blue Sphere; Phenix	Blue Sphere; Phenix	Phenix	Keenan Recycling	

Table 2 – Analysed case studies mapped along the FSC and layers of the FWH

4.2. Business models for sustainability adopted along the food supply chain

Table 3 provides an overview of the business models of the startups in our sample. Many startups combine, in creative ways, the archetypes by Bocken et al. (2014). It is noteworthy that “maximize materials and energy efficiency” (T1) and “create value from waste” (T2) are the mostly leveraged archetypes. T1 is adopted as a stand-alone business model or in combination with other archetypes. Companies opting for this archetype as a stand-alone approach (7 cases in our sample) are technology providers that make food waste prevention software (e.g., Wasteless and Fresh4Cast), or packaging suppliers that provide solutions to extend the shelf-life of food products (e.g., Cronograd). In 12 other cases, the T1 archetype is implemented in combination with other business model archetypes. Copia, a US-based startup, for example, provides a technological platform to manage the redistribution of surplus food (i.e., the reduction of waste), and additionally

collects data to support companies along the food supply chain to make informed food purchasing decisions. Consequently, Copia is acting proactively to sustain virtuous initiatives along its supply chain, while adopting a stewardship role, which is also a social archetype by Bocken et al. (2014).

“Create value from waste”, the T2 archetype, is rarely implemented as a stand-alone approach in our sample. Indeed, it is always combined with other archetypes, in particular socially-focused business models such as “adopt a stewardship role” (16 cases). This combination of archetypes is typical for companies that transform food waste to new edible or non-edible outputs sold in supply chains of other industries or adopted as input materials for bio-based packaging (e.g., Chemicle). The same archetype has been implemented by those startups (e.g., BellaDentro, Babaco market, Imperfect Foods) that sell “ugly products”, which are fresh fruits and vegetables that would normally not meet the aesthetic standards of the traditional retail channels. The sale of such products is driven by a new set of ethical values, while communicating the stewardship role to customers.

Three companies in our sample combine “maximize material efficiency” (T1) with “adopt a stewardship role” (S1) and “repurpose for society and environment” (O1). For instance, Food Cloud is a social enterprise that connects companies along the food supply chain to local charitable organizations and community groups to redistribute surplus food. Thus, Food Cloud’s business model reduces food waste, maximizes material efficiency and has a clear social mission.

These results are in line with Bocken and Short (2016) who acknowledged that the archetypes should not be interpreted as silos, and companies can capitalize on the synergies that result from combining different archetypes. By implementing different archetypes at the same time, companies stress many facets of sustainability.

Bocken et al. (2014) set of archetypes		Case studies
T1	Cronogard Easyls Fresh4cast Wasteless	Insignia Technologies MatSmart Shelf Engine
T1 + T2 + T3	Apeel Sciences IUV	
T1 + S2 + O1	Copia Spoiler Alert	
T1 + S2	Goodr Winnow	
T1 + S1 + O1	Food Cloud OLIO Phenix	
T1 + S1	BringTheFood Karma Too Good To Go	
T2	Blue Sphere TripleW	
T2 + T3	Bio-Bean Chemicle Do Eat Packtin	
T2 + S1	Babaco market Barnana Bella Dentro Biova Entocycle Full Harvest Imperfect Foods Keenan Recycling Mialgae	Peelpioneers Regrained Renewal Mill RiceHouse riseproducts Rubies in the Rubble WTRMLN WTR

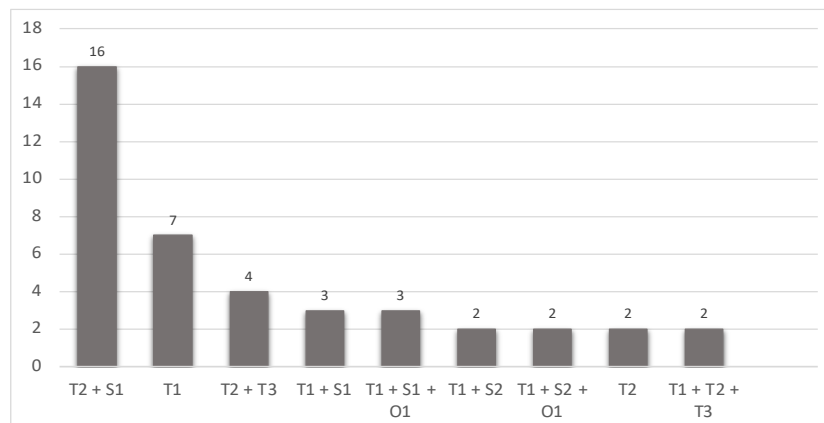
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441

442 *Table 3– Analyzed case studies classified according to Boken et al. (2014) BM archetypes*

443 'T1 = Maximize material and energy efficiency; T2 = Create value from waste; T3 = Substitute with renewables and
 444 natural processes; S1 = Adopt a stewardship role; S2 = Encourage sufficiency; O1 = Repurpose for society/Environ
 445 ment. Case studies refers to Table 4.

446



447

448 *Figure 2 – Frequency of sample startups for each of the sustainable business model archetype (or*
 449 *archetype combination)*

The results shown by Table 2 and Table 3 reveal that business models for sustainability have been developed at every stage of the supply chain where food waste is generated. In addition, different types of business models have been found in every stage. Hence, it cannot be stated that some business model archetypes are more likely at particular stages of the supply chain than others.

4.3. The role of big data

The startups' leverage of BDA is analyzed by means of a two-by-two matrix with two dimensions: (1) current BDA exploitation (or also BDA capabilities, which depend on the adopted steps in the data value chain: data discovery, integration, and exploitation), which can be high or low, and (2) future BDA potential in food waste reduction (Ability to leverage BDA capabilities in the support of current or ever higher levels in FWH), which also exhibits two levels: high and low.

Based on cross-case analysis reported in Table 4, we can derive four clusters of startups (Figure 3).

#	Company	Year of foundation	Short Description	Quadrant of the matrix ¹	Bocken et al. (2014) set of archetypes ²
1	Apeel Sciences	2012	Creation of protective extra peel to make fresh products last longer	4	T1 + T2+T3
2	Babaco market	2020	Resells "imperfect" fruits and vegetables to final customers	3	T2 + S1
3	Barnana	2012	Makes use of upcycled bananas and sustainably harvested plantains to create products. Supports regenerative and fair farming practices with indigenous communities.	3	T2 + S1
4	Bella Dentro	2017	Utilized "imperfect" and discarded fruits and vegetables from farmers selling them directly to final customers or remanufacturing them	3	T2 + S1
5	Bio-Bean	2012	Recycles spent coffee grounds from cafes and restaurants, offices, universities, instant coffee factories, etc. into a broad spectrum of efficient, sustainable products for a range of markets, both consumer and industrial.	3	T2 + T3
6	Biova	2017	Utilizes waste coming from bread to produce beer	3	T2 + S1
7	Blue Sphere	2007	Transforms agricultural, municipal, and industrial waste into sustainable, clean energy and other by-products.	3	T2
8	BringTheFood	2012	Redistributes surplus food from suppliers, GDO and restaurants to charity organizations	3	T1 + S1
9	Chemicle	2019	Converts components of cheese whey into high-performance bioplastics by means of chemical process developed by the company	3	T2 + T3
10	Copia	2016	Collect surplus food from restaurants, hotels, hospitals, corporate cafeterias, and other businesses to: - Collect data, understand overproduction trends, and reduce surplus over time (customers receive powerful data to inform food purchasing decisions) - Redistribute excess food to local no-profit organizations	2	T1 + S2 + O1

11	Cronogard	2011	Offers an innovative packaging designed with a new technology that inhibits the deterioration of fresh packed food	4	T1
12	Do Eat	2013	Creates food recipients made from natural and edible products completely compostable and edible	4	T2 + T3
13	Easilys	2010	Provides complete software solution that allows food service businesses to manage and optimize their back office (supply, stocks, production, food waste ...)	1	T1
14	entocycle	2014	Utilizes local food waste — rejected supermarket fruit and vegetables, brewer's grains, and coffee grounds — to feed insects which eat the waste and convert it to protein and produce products for plants and animal feed.	3	T2 + S1
15	Food Cloud	2013	Connects by means of a platform, businesses that have surplus food (ranging from agriculture to retailers) with charities and community groups that need it.	3	T1 + S1 + O1
16	Fresh4cast	2013	Platform for SC Optimization and Food waste reduction	1	T1
17	Full Harvest	2015	Helps farms capture oddly shaped and surplus products to be sold in their B2B marketplace for food manufacturers.	3	T2 + S1
18	Goodr	2017	Tracks an organization's surplus food from pickup to donation, thus delivering real-time social and environmental impact reporting analytics.	2	T1 + S2
19	Imperfect Foods	2015	Utilizes "imperfect" products discarded from manufacturers or retail stores and re-sell them directly to customers or re-manufacture them.	3	T2 + S1
21	Innovative Utility Vehicle (IUV)	2019	Produces a microfilm for the packaging of fresh food and utilizes food waste to create packaging for non-food products	4	T1 + T2+T3
20	Insignia Technologies	2012	Offers intelligent packaging solutions, i.e., smart labels that change color when the package is open, for improving food freshness and quality	4	T1
22	Karma	2015	Connects surplus food from retailers to consumers for a discounted price.	3	T1 + S1
23	Keenan Recycling	2003	Collects food waste from food service businesses to transform it into electricity, heat, and fuel	3	T2 + S1
24	MatSmart	2014	Sells at a discounted price food that would have otherwise been thrown away for overproduction, incorrect packaging, seasonal trends, short or sometimes passed best before dates reasons and delivers the food to the customer.	3	T1
25	mialgae	2016	Recycles co-products from food and drink production to grow Omega-3 rich micro-algae, returning clean water in the process.	3	T2 + S1
26	OLIO	2015	Provides a Marketplace that connects households, food services, and retailers to exchange leftovers at a discounted price that would have otherwise been wasted	3	T1 + S1 + O1
27	Packtin		Utilizes food waste (e.g., fruit peel or pulp) from manufacturers to create biodegradable film as food "packaging" to increase fresh products shelf-life	3	T2 + T3
28	peelpioneers	2018	Utilizes orange peels from retailers or food services to produce products re-usable in the food industry like oils but also non-edible products like detergents.	3	T2 + S1
29	Phenix	2014	Gives a second, responsible and united life to unsold products, sells the food at a reduced price on the Phenix mobile app, makes donations to charities, makes donations for animal feed, produces compost, and makes the methanization formation of the rest unsold products	1	T1 + S1 + O1
30	Regrained	2013	Utilizes rescued grain from beer production to create new products	3	T2 + S1
31	Renewal Mill	2016	Utilizes byproducts of plant-based milk production to create new products	3	T2 + S1

32	RiceHouse	2016	Utilizes non-edible rice waste coming from agriculture to create architecture parts.	3	T2 + S1
33	riseproducts	2017	Utilizes Brewer's Spent Grain to create new products	3	T2 + S1
34	Rubies in the Rubble	2012	Processes vegetables recovered from the farms to create new products	3	T2 + S1
35	Shelf Engine	2015	Automatically submits the store's ideal order to the vendor calculated using POS data along with real world considerations like holidays, and weather data. They also buy back what doesn't sell.	1	T1
36	Spoiler Alert	2015	Provides Software platform for food manufacturers and wholesalers to manage discount sales and donation processes for slow-moving, excess, discontinued, and distressed food inventory	1	T1 + S2 + O1
37	Too Good To Go	2015	Sells at a discounted price food that would have been otherwise thrown away by restaurants, supermarkets, or fresh food vendors (e.g., bakeries). The order pick-up is performed by the customer.	3	T1 + S1
38	TripleW	2015	Upcycles food waste into high-value bioplastic	3	T2
39	Wasteless	2016	Provides an all-in-one ML/AI solution for supermarkets and online grocery stores to solve high dimensional dynamic programming problems and automatically maps inventory stock and time of day into a series of optimal prices. Quickly learns how consumers respond to dynamic pricing to find the optimal discounting policy.	1	T1
40	Winnow	2013	Provides an AI-enabled device that reads what people throw in the trash, collect the data, and elaborates reports to maximize operational efficiency and data accuracy in restaurants or canteens with the objective of reducing food waste.	2	T1 + S2
41	WTRMLN WTR	2013	Utilizes "discarded" melons to create a new beverage product	3	T2 + S1

Table 4 – Cross-case analysis. Labels in the last column refer to RQ2.

¹1= Advanced BDA and FWR leverage; 2=Advanced BDA for untapped FWR opportunities; 3= Potentially useful BDA for untapped FWR opportunities; 4=No BDA?

²T1 = Maximize material and energy efficiency; T2 = Create value from waste; T3 = Substitute with renewables and natural processes; S1 = Adopt a stewardship role; S2 = Encourage sufficiency; O1 = Repurpose for society/Environment.

In six out of 41 cases (lower right quadrant of the matrix), BDA was highly exploited and leveraged in FW applications, thus exhibiting low future potential in further supporting food waste reduction. These companies are advanced in BDA and FW applications (**Advanced BDA and FW leverage**). They collect, visualize, and draw on analytics for decision making to tackle food waste at higher layers of FWH by addressing waste at its root causes. They have technological solutions that allow more accurate forecast, foster a better match between supply and demand, directly tackle the issue of food waste, and support decision making. For example, Wasteless, an Israel-based startup, provides machine learning-based solutions that help solve dynamic programming problems, automatically map inventory stocks, and depending on food stock, assign dynamic pricing. The company's software learns how consumers respond to dynamic pricing to find an optimal pricing strategy that minimizes food waste.

Companies in the upper right quadrant of the matrix have already adopted BDA to tackle FW, but just marginally. There are still higher levels in the FWH that the company can potentially address with BDA. The current exploitation level of BDA is, however, high. Companies in this quadrant are called *Advanced BDA for untapped FW opportunities*. Despite the high level of BDA capabilities, the startups in this quadrant do not fully reap the potential of BDA in reducing food waste. This is the case of companies that offer data visualization and data monitoring services, but do not address high FWH levels with BDA. For example, the Swedish startup Winnow leverages BDA and artificial intelligence to allow restaurants gain visibility on the kitchen's food waste, thus implying a high exploitation level of BDA. However, BDA could have been potentially used for more direct and effective actions regarding food waste through prediction and prescription of actions that aim to reduce food waste.

In the upper left quadrant of the matrix (*Potentially useful BDA for untapped FW opportunities*), current exploitation level of BDA is low (only data discovery and/or integration), but BDA has the potential to enable the company to support better its position in the current FWH layer, or even achieve a higher FWH layer, and overcome problems related to “closing the loop”. Startups in this quadrant generally leverage *reuse* and *recycling* options along the FWH. BDA can, for example, favor a better forecast and management of the input flows for recycling. Take the example of Regrained, a British startup that implements reuse edible surplus food from the brewing process to create a new food ingredient with rich nutritional properties. Because it utilizes rescued barley from beer production to produce snacks, it is most likely that the company is exposed to a high variability of quantity, quality, and variety of barley. If collected, these inputs would eventually generate BD that the company can potentially use to better leverage food waste. Thus, in the long run, BD could be an important asset for the firm to ensure business stability and good operational performance. A slightly different case is Olio, which provides a marketplace that connects households, food services, and retailers to exchange food leftovers at a discounted price. Data on food leftover availability and product range, as well as requests from recipients are collected, but this data is not exploited to directly tackle higher FWH levels, e.g., the prevention of food waste. Thus, for companies in this quadrant, BDA represents a potential supporter to solve food waste challenges. These companies, therefore, tend to achieve food waste reduction by capitalizing on other solutions, though BDA could have potentially provided additional support, even to jump to a higher layer in FWH.

Finally, the lower left quadrant of the matrix, consists of five startups. For these startups, BDA is neither exploited, nor it is evident that it could be used to cope with food waste. Food waste issues are already tackled without BD. Given the unclear potential of BDA for these cases, we call them the “*No BDA?*” companies.

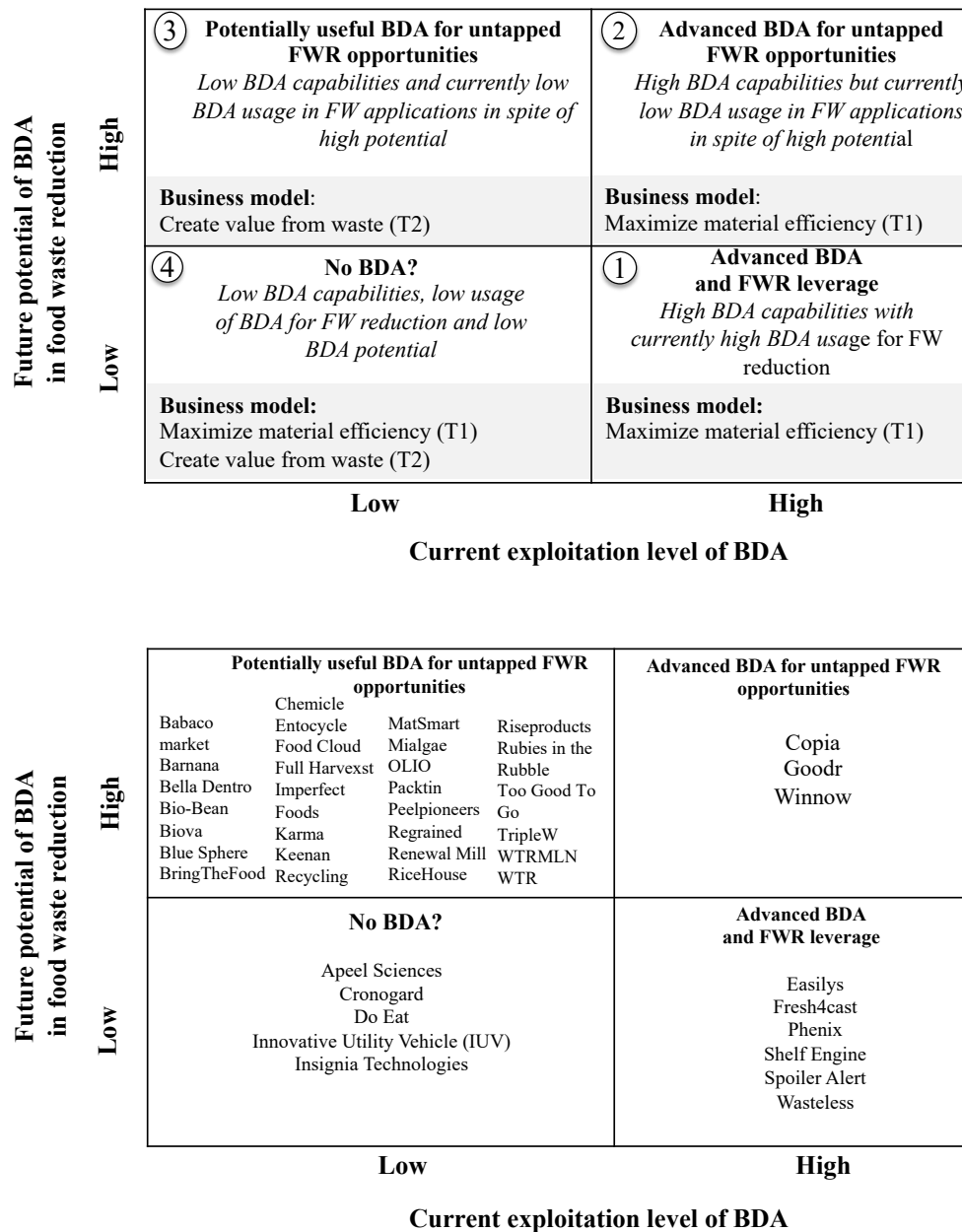


Figure 3 – Startup clusters that result from relating the current exploitation level of BDA to its future potential in reducing food waste

5. Discussion

The results allow us to provide answers to both research questions that are formulated in the introduction. Regarding RQ1, the empirical evidence supports that, at all stages of the

supply chain where food waste is generated, business models for sustainability can be applied. Moreover, the type of business models observed does not depend upon the stage of the supply chain.

As far as RQ2 is concerned, after having analyzed the startups business models and BDA exploitation/potential independently, we connect business models to BDA in this section. Our discussion leads to the formulation of propositions regarding how business models for sustainability may leverage BDA.

As shown in Figure 2, the companies that aim at maximizing material efficiency (T1 business model archetype) have high BDA exploitation level (clusters 1 and 2). Companies that create value from waste (T2 archetype) have currently low BDA capabilities, but if they exploit BDA in the future, they can potentially tap unexploited FW opportunities (cluster 2). The cases belonging to cluster 4 “No BDA?” are, in our sample, all packaging technology providers. These companies use packaging to extend the food product shelf life (T1), or to produce the packaging itself by capitalizing on recycling activities (T2). Based on these first observations, we can formulate the following proposition:

Proposition 1 (Correlation Business model-BDA)

In the context of agri-food supply chain, the business model for sustainability “Maximize material efficiency” is more likely to go hand-in-hand with high BDA capabilities, whereas the business model “create value from waste” can be applied without necessarily leveraging BDA.

In the **advanced BDA and FW leverage** cluster, companies prevent the creation of food surplus, thus avoiding food waste at its roots. Despite high performance, these companies are interested in making their processes of food waste avoidance increasingly efficient, as achieving 100% efficiency is rather ideal and ambitious objective. Companies in cluster 2 **Advanced BDA for untapped FW opportunities** have high technological BDA capabilities, but the potential in food waste reduction is still not fully exploited as in cluster 1. These companies use the same basic business model (T1) as those in the first cluster. Because of their high BDA capabilities, companies in cluster 2 record food waste data and exploit this data to support their business. As indicated by Martin-Rios et al. (2021), companies should measure key performance indicators (KPIs) related to food waste to achieve observable performance improvements. Companies in

cluster 2 seem to be aware of their achieved performance improvements. Nevertheless, these improvements might have caused them to only focus on the exploitation of “low hanging fruits”, in spite of their higher capabilities that would enable them to achieve even better performance.

By increasing their efficiency levels through BDA—which is possible due to their high capabilities—companies in cluster 2 can improve waste reduction, in a way they can make the transition to cluster 1. In other words, if cluster 2 companies keep the same business model over time and increasingly capitalize on BDA, they will be able to shift to the Advanced BDA and FW leverage cluster. Hence, the following proposition:

Proposition 2 (Transition paths of “Maximize Material Efficiency” Business Models)

Companies that maximize material efficiency are likely to be aware of the importance of BDA capabilities for their business model. They can first start by developing BDA capabilities, and then leverage BDA over time to increasingly improve their performance with respect to food waste reduction.

The shift from cluster 2 to cluster 1, which represents companies with an advanced use of BDA and FWR leverage, would presumably correspond to what Mourad (2016) calls weak forms of food waste prevention because this shift is primarily due to resource optimization. According to Mourad (2016), a strong form of food waste prevention rather takes place after a radical change in the business model and will likely enable the company to survive in the long run. The author argues that process optimization results in a better fit of food supply and demand, thus leading in the long term to decreasing profitability, since customers would end up buying less. For example, the concept behind “zero waste” apps is to make customers at different levels of the supply chain become aware of how much food they really need to buy in order to fulfill their needs. The apps propose quantities that are much lower than what customers would have otherwise purchased without app support. In other words, when the “zero waste” philosophy is shifted downstream to final consumers, this will cause a decrease in revenues for the whole supply chain, without necessarily getting a compensation in terms of cost reduction.

Our research sheds light on the boundary conditions of Mourad (2016)’s results. When resource optimization is only concerned with customer’s buying behavior, then we

are facing a weak form of food waste prevention that is probably not long living and therefore short-term. Because of a deteriorating profitability, companies, sooner or later, will have to change their business models. However, by leveraging BDA for cost reduction and efficiency improvement along the supply chain, profitability may still improve despite steadily decreasing levels of customer demand. Thus, different from what Mourad (2016) posits, companies can still develop to zero waste companies by sticking to the same business model, while increasingly leveraging their BDA capabilities. Consequently, business model change does not seem a necessary condition to achieve a strong form of food waste prevention.

Companies in cluster 3 *Potentially useful BDA for untapped FW opportunities*, however, aim at “closing the loop” because they create value from waste. These companies are looking for ways to manage food waste after it is generated, while not necessarily leveraging BDA at their early stages. Thus, companies, in cluster 3, do not start by developing high BDA capabilities, but rather uncover the potential of BDA in supporting their business model. In our sample, we do not have companies that close the loop and exhibit high BDA exploitation level. Because of this, we do not know, whether such companies are currently existing or not. Sure enough, however, because the potential benefits of BDA in food waste reduction is high, we can hypothesize that there **is**, or—at least— there **will be** companies in the future that close the loop and capitalize on BDA. This, among others, is also one of the paths delineated in the roadmap elaborated by De Souza Jabbour et al. (2018). Even if the context is not food specific, the authors identified BD that are collected through Internet of Things (IoT) technologies, as an important leverage for the support of logistics and reverse logistics processes that lead to less planning uncertainty when companies *close the loop*. Consequently, we can formulate the third proposition:

Proposition 3 (Transition paths of “Create value from waste” business models)

Companies in the agri-food supply chain that create value from waste are likely to start by capitalizing on their business models, while trying to uncover the potential of BDA applicability. Once the potential benefits of BDA are clarified, these companies can decide to develop high BDA capabilities to improve their performance in closing the loop.

Proposition 3 is in accordance with the expectation that companies that close the loop should clarify the potential benefits of BDA before embarking on such an endeavor. Our

analysis provides support that BDA application and benefits are more straightforward for companies that maximize material efficiency, but less obvious for companies that create value from waste. It seems that BDA is at the core of business models that aim at maximizing efficiency, whereas the opportunity arising from value creation out of waste is the essence of business models that close the loop with BDA rather representing a possibility for further improvement than a necessary requirement. This can be explained as follows. Companies that create value from waste need resources and capabilities that lie outside the activities of the core food supply chain. They need to establish collaborations with process technology providers to perform reuse and recycling operations. They face barriers in managing food waste because of high waste supply uncertainty and difficulties in effectively planning production activities. Therefore, they have to clarify the requirements of their business models with respect to data before building up BDA capabilities. Companies that “maximize efficiency”, however, rely on linear supply chains. To prevent the generation of surplus food, they need technological competencies and resources that they can develop themselves or get access to through partnerships. Thus, the need for technological capabilities of the “maximize efficiency” companies is more straightforward than when companies aim to close the loop. Based on this, we can formulate the following corollary:

Corollary (BDA relevance for the business model)

Companies in the agri-food supply chain that want to close the loop, do not seem to be BDA driven, instead they seem to be driven by the strategic intent to better manage and create new value out of food waste. However, companies that maximize material efficiency are more likely to be driven by BDA technology.

In line with our insights, Halloran et al. (2014) also acknowledge the importance of BDA to support the prevention and management of food waste. Regarding food waste prevention, the authors underline the key role of knowledge and information sharing among supply chain actors to implement food waste optimization and better steer selling and procurement activities. As far as food waste management is concerned, companies need data about how much food is wasted and information about its potential in being post-processed for animal feed products or other applications (i.e., for closing the loop).

Companies in the cluster “No BDA” may opt for the business model “maximize material efficiency” (T1), by offering innovative packaging technologies to prolong food shelf life, thus avoiding a rapid food spoilage. These are examples of T1 which opt for a technological solution other than BDA, to prevent food waste.

In some cases, T1 archetype appears in combination with “closing the loop” (T2), when the packaging solution to prolong food shelf life is also made from recycled food scraps.

Therefore, the cluster “No BDA?” can contain two types of companies: companies that do not need BDA at all and will continue doing their business without this technology, rather leveraging innovative packaging solutions, as well as companies that will develop their business by following the transition paths illustrated by propositions 2 and 3.

Apart from connections to the literature on food waste, our study seems connected to more general literature. In particular, the corollary above is tightly related to the discussion regarding Information Technology (IT) strategic alignment (e.g., see the seminal paper by Hendersen and Venkatraman (1993)). The literature on strategic alignment discusses, among others, whether business strategy informs IT strategy and infrastructure or vice versa (e.g., Coltman et al., 2015). In other words, is IT reactive to business strategy, or a driver of business strategy development (Coltman et al., 2015)? Being aware of the conceptual differences between business strategy and business model, as “business models are reflections of the realized strategy” (Casadesus-Masanell and Ricart, 2010, p. 204), our findings seem to support the bidirectional relationship between business strategy and IT. Companies that close the loop are primarily business model driven. Hence, IT infrastructure—BDA in our case—seems to follow business strategy. However, BDA capability development is a necessary condition for resource optimization, and therefore precedes the execution of the “maximize material efficiency” business model. IT selection and development are, therefore, ahead of business strategy.

In addition, our findings contribute to the literature on digitalization and business models, by better shaping the two opportunities that, according to Ritter and Pedersen, (2020), can result from the application of digitalization capabilities to business models: data can be exploited in existing business models, or (partially) new digitized business models can be explored. In this line, we distinguish two types of business models: digitally-enabled business models and digitally-supported business models. *Digitally-enabled business models* are driven by information technology, as technology is essential

for the proper functioning and execution of the business model. “Maximize material efficiency”-business model is BDA enabled. *Digitally-supported business models* can improve with technology, while technology is not an integral part of the business model. In other words, the business model can function correctly, even in the absence of sophisticated information technologies, as it is the case for “create value from waste” business models. Obviously, both types of business models need different approaches to IT.

6. Conclusions

This paper tackles the challenge of how to mitigate the environmental and social impact of food waste generation. It investigates the business models along the food supply chain that avoid food waste generation or create value out of it. In addition, it examines how BDA can support these business models. Our analysis is based on 41 selected start-ups (technology and service providers) for which we collected data from secondary sources.

We contribute to the literature in different ways. First, we systematize the knowledge related to the causes of food waste generation along the stages of the food supply chain. Second, we argue that food waste can be tackled by business models for sustainability at every stage of the supply chain where the waste is created. Third, in the attempt to answer the call by de Sousa Jabbour et al. (2018), we make a first conceptual step toward the provision of more empirical evidence on how BDA can support sustainable business models. Our results show that in a linear supply chain, business models rely on BDA to achieve food waste prevention. However, business models that create value from food waste by building circular supply chains still do not exploit BDA. Therefore, companies that tackle food waste prevention in a linear supply chain are aware of the potential of BDA and increasingly exploit it until they achieve a high level of BDA exploitation, whereas companies that generate value from waste start by building circular supply chains, and only then may progressively include BDA.

Hence, BDA is likely to be used for the mitigation of food waste in linear supply chains, and it is less likely to be leveraged by business models that create value out of food waste within a circular food supply chain. Consequently, whereas BDA seems a more necessary requirement for business models that are focused on optimizing a linear supply chain, it appears, at least at the time being, to be rather optional for business models closing the supply chain loop.

Our results contribute to the general debate on digitalization and sustainability. It provides compelling evidence that digital technologies can drive and support sustainability. Our insights are also relevant from a practical point of view, in that we present a set of business models for sustainability that are suitable for tackling food waste prevention and management. Moreover, we provide managers with a matrix where they can map their business models to identify potential development of their business. Finally, our compiled case study database provides evidence on how BDA can be useful for tackling food waste.

The main limitation of our research is that it relies on secondary data sources. Therefore, in the future, our study could be expanded by designing and conducting case studies with companies along the supply chain, while leveraging primary data sources. The case studies can deliver rich insights that support and eventually refine our propositions. Future research can also deal with the barriers hindering the integration of BDA-based solutions or technologies such as packaging for extending the shelf life of food. From our research, we could not derive insights into how companies aiming to reduce food waste can develop their BDA capabilities. These companies may select out of a menu of different options such as buying ready-to-use solutions, developing their own approaches to BDA for food waste reduction, or by collaborating with external partners, but the optimal option may depend on certain contingencies that are still to be discovered. From a general viewpoint, we believe that new technologies combined with appropriate business models can unfold an unprecedented potential in supporting the sustainability targets of companies and whole industries, and it is the role of conceptual and evidence-based research alike to provide practical support in this regard.

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