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Research article

Moving towards circular bioeconomy: Managing olive cake supply chain through contracts

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ABSTRACT

Circular bioeconomy represents a recent political vision expected to contribute in tackling the main challenges faced when sustainable industrial transition trajectories are to be implemented. Coordination and interdependence among actors are crucial steps for value creation when developing new sustainable supply chains. Current study is based on a choice experiment devised with contract design theory applied to a specific supply chain in which a circular bioeconomy strategy is implemented. It investigates the propensity of Sicilian millers to participate in a novel supply chain in which feedstuff is produced by processing a by-product, namely olive cake. Furthermore, millers contract attributes' preferences are analysed. The results from two econometric models reveal that 71% of the interviewed entrepreneurs would participate in the proposed supply chain while the propensity to participate is positively related with firm size and millers' attitudes but decreases if millers experienced previous investments or have previously participated in cooperatives. Moreover, respondents prefer shorter length of contract, with a minimum guarantee price, with a renegotiation option, and without the obligation of a minimum volume of product to be supplied. Contract agreements, when contract characteristics are designed ad hoc, are proved to be effective tools for circular bioeconomy supply-chain development.

1. Introduction

Over the last few years, the debate on enhancing the sustainability of industrial systems has gained momentum, pushing interest in bioeconomy (BE) (Nankya et al., 2017) and focusing on closed-loop supply chains (Ghisellini et al., 2016; Schroeder et al., 2019). Globally, several countries have been showing increasing interest in adopting transition strategies by applying BE-related policies (von Braun, 2018) as well as making efforts to reshape industrial systems, following the idea of a zero-waste economy, towards the circular economy (CE) model (Kerdlap et al., 2019). These strategies have been put forth by almost 50 countries across the globe (Fund et al., 2018), been used as part of the European Green Deal (European Commission, 2019) in which, among others, the support of supply and the use of renewable sources of energy, by-products, wastes, and residues are included.

In this political context, the BE and CE concepts are strictly interconnected. On one hand, widely speaking, BE deals with a transition towards a bio-based economy, i.e., converting waste materials into value added products such as food, feed, and bioenergy to assure, moreover, food security and conservation of natural resources (Hess et al., 2016). On the other hand, CE transition is seen as a model to redirect the path of economic development and revert societal and environmental effects to earlier stages in which planetary boundaries were not exceeded (Steffen et al., 2007). The CE narrative proposes a future in which the concept of waste is phased out, aiming at a model of economy that overcomes the actual effects of human activities that exceed the resilience of ecosystems on a global scale (Borrello et al., 2020b). Even though BE and CE appear to be tangential models (Korhonen et al., 2018), they seem to reinforce each other when it comes to transitioning an industry towards a sustainable model of production. For

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Nomenclature

BE	Bioeconomy
CE	Circular economy
OC	Olive cake
CBE	Circular Bioeconomy
DCE	Discrete Choice Experiment
PtP	Propensity to Participate
PBC	Perceived Behavioural Control
TPB	Theory of Planned Behaviour
RUM	Random Utility Model
EFA	Exploratory Factor Analysis

instance, the Circular Economy Action Plan (European Commission, 2015) recognises BE as the main pillar of the CE. The political vision of BE is often specified as a circular bioeconomy (CBE) (Stegmann et al., 2020) since the BE strategies are expected to contribute to the CE transition (Hetemäki et al., 2017). However, despite the fact that EU communication on the CE places a great emphasis on food waste and agricultural by-products, only 40% of waste is currently recycled in European countries, while the majority of potential secondary raw materials is dumped into landfills (European Commission, 2015). In this regard, Stenmarck and colleagues (2016) estimated that the EU annually produces around 88 million tons of food waste, of which more than 30% is agro-industrial food waste. In this scenario, agricultural waste and by-product valorisation may be functional for creating economic benefits and for reducing the negative environmental impact of dumped waste (Donia et al., 2018).

Although the perspective of reconciling global industrial systems with natural equilibria by means of closed-loop processes seems to be intuitive, agreed upon by governments, and reasonable, a method to implement CBE principles in the agri-food industry is still unclear (Borrello et al., 2020a; Stegmann et al., 2020) Indeed, the path from theory to field implementation is far from straightforward, and developing a CBE industry requires tackling several challenges and facing them is crucial for determining which transition trajectory would be the most effective (e.g. BE utilisations of secondary products in restorative in-farm practices) (Stegmann et al., 2020).

With this as the starting point, we aim to take a step forward by conducting a study based on a choice experiment devised with the help of contract design theory applied to a specific supply chain to which a hypothetical, though likely to be realistic, CBE strategy is implemented. To illustrate, we aimed at tackling two research questions: i) identifying the main factors affecting the decision of a representative sample of Sicilian millers to take part in the CBE supply chain and ii) assessing millers' preferences for contract attributes. To answer the first question, we have firstly captured millers' attitudes and motivations to participate in the olive cake (OC) supply chain by means of the Theory of Planned Behavior (TPB) constructs (Ajzen, 1991) and then we have analyzed them through a Probit model. As for the second research question, a choice experiment will provide millers' preferences for contract alternatives that will be analyzed by adopting a Conditional Logit model.

While the development of the CBE supply chain largely depends on a supplier's willingness to participate in the new venture, a contract design preference approach is needed to reach efficient and resilient supply coordination (Gil and Zanarone, 2018; Raimondo et al., 2018). Several studies have highlighted that one key element for developing CBE supply chain concerns the nature and intensity of relationships among stakeholders, since a strict interrelationship between stakeholders is required (Carraresi et al., 2018). Contract mechanisms are often used to manage coordination and integration of a supply chain since they provide flexibility in the way incentives can be set for different typologies of suppliers, thus increasing the chances of large-scale participation (Abebe et al., 2013).

A case study approach is followed here; therefore, the specific supply chain involving the valorisation of the solid residue of the olive oil industry, namely OC, in Sicily, Southern Italy, was considered since the transition management depends on the specificity of a supply chain, or industry, under consideration (Borrello et al., 2020b). In the Mediterranean area, olive oil has large economic relevance in terms of production and consumption (Salomone and Ioppolo, 2012; Tanasijevic et al, 2014). Italy is the second largest European producer of OC after Spain. Within Italy, Sicily is the third (after Apulia and Calabria) largest region in olive oil production (Di Vita et al., 2015). Since 30% of fresh fruit is dried OC (Morillo et al., 2009), Sicily produces about 80,000 tons of by-product. Accordingly, the OC transformation to feed animals is gaining increased attention (Taticchi et al., 2017). OC is a valuable resource post appropriate processing (Chinnici et al., 2015). Previous research has highlighted the possible use of OC to develop innovative and functional products (Uribe et al., 2013) and/or to produce active carbon (Stavropoulos and Zabaniotou, 2005), while other potential uses of OC include: i) animal feed (Suàrez et al., 2009), ii) fertiliser for agriculture (Mirabella et al 2014), or iii) biogas (Chinnici et al., 2018) and biofuel production (Brlek et al., 2013). The former was chosen, among the three above-mentioned potential uses of OC, because the livestock sector (in terms of sheep, cattle, and buffaloes) in Sicily is largely diffuse (around 1.2 million livestock units) (ISTAT, 2020) and OC use would reduce feed costs and improve the quality of milk and other dairy products (Berbel and Posadillo, 2018). Moreover, as will be argued in the following paragraph, feedstuff production represents one of the most efficient ways to create value out of a biomass. Despite its potentiality, the actual use of OC in Sicily is the production of energy, e.g. fuel, fire, electricity, heat and biofuel (Chinnici et al., 2018), which means building an alternative, new, supply chain aiming at further valorising this biomass. The reason it has not happened yet is, very likely, related to several bottlenecks that are, to name a few: the very short time period (October–February in the Mediterranean region) of OC availability, which lowers the economic convenience of processing OC due to plants' underuse (Ghimire et al., 2015); and the large availability of raw material concentrated in that short period (about 80,000 tons) generates an excess of supply, lowering market prices. Moreover, economic convenience is even further worsened by the transportation costs from millers to OC processor/s. Therefore, a supply coordination through contracting among stakeholders is needed for releasing the hidden value of this by-product, and contracts need to be properly designed to increase the efficiency and performance of the interrelationships within supply chain actors.

Drawing from a stated choice experiment involving a sample of 201 OC suppliers operating in Sicily, results of the current study identify main factors influencing the decisions of millers to participate in a realistic[1], though hypothetical, supply chain in which feedstuff is produced: The role played in this process by millers' attitudes and motivations will be identified by means of the TPB constructs (Ajzen, 1991). Secondly, the preferences of millers for different contract attributes will be provided in order to identify the most preferred contract design that may support the development of the OC supply chain.

[1] An anonymous reviewer questioned the term realistic. Since we agree that it could bring some confusion, we intend to clarify why we used this term. The supply chain under analysis is about to be ready to be started, but not yet in place, hence hypothetical.

The current study is innovative in three areas: First, it introduces a two-step analysis that makes the choice path entrepreneurs follow when it comes to decide whether to participate realistically; second, it sheds light on a specific biomass (namely OC) that is only scantly covered in the literature in terms of supply chain management; third, the analysis contributes to the recent literature on CBE.

The remainder of this paper is organised as follows: Section 2 clarifies the concept of CBE and then summarises previous research on contract farming applied to managing new supply chains. Section 3 includes an overview of the survey design, Section 4 describes the statistical method, and the results of the models are reported and discussed in Section 5. The last section concludes the work and provides the significance of the study.

2. Theoretical background

The current paragraph summarizes the main pillars of the theoretical background followed in this study. It is divided in three subsections. The first one concerns concepts and implications of the CBE going into some details of CE and BE separately and then considering them as a whole elaborating on its operational implications. The second subparagraph highlights main findings on the role of contract mechanisms for managing supply chain coordination. The third subsection provides the theoretical framework of current study by illustrating how CBE and supply chain coordination merge in unique and coherent framework of analysis.

2.1. Circular bioeconomy: concepts and implications

A resource-efficient use of biomasses has been tackled by a number of conceptual frameworks and approaches with a common aim to identify strategies for reaching global sustainability goals (Borrello et al., 2020b). Governments' BE strategies have increasingly considered the concept of CBE (Fund et al., 2018). This concept merges BE strategies that consider biomass to play an important role in meeting global sustainability targets (Daioglou et al., 2019) and CE to overcome the risk of following an unsustainable linear business-as-usual approach (Hetemäki et al., 2017).

Before the term CBE was first coined, the Ellen MacArthur Foundation (2013) implied that BE was a part of CE, including it in the biological nutrients cycle. Other studies have described the perspectives on CBE in relation to BE and CE, looking at the common areas of BE and CE (Carus and Dammer, 2018; Venkata et al., 2019), while others have argued for a wider vision, looking at CBE as a type of interaction that belongs to a larger concept than BE and CE alone (D'Amato et al., 2018; Hetemäki et al., 2017). Aside from the different perspectives on the definition of CBE, CBE helps to reach a more balanced approach towards a sustainable transition, allowing for the definition of resource-efficient use of biomasses. To illustrate, the impact of CBE on biomass use has changed. Using biomass directly for energy or fuels makes it impossible for it to maintain its value via reuse or recycling (Carus and Dammer, 2018). In CBE, a biomass would ideally first be delegated to a material use and then used again in multiple cascading steps. An efficient and highly developed CBE strategy takes the biomass value pyramid (Berbel and Posadillo, 2018), which refers to the cascading principle depicted in Fig. 1, into consideration.

Fig. 1 indicates that applications such as fine chemicals or pharmaceuticals are generally where one would want to use biomass. The residues from such processes could be used lower in the pyramid. Nevertheless, since not all biomass is suitable for the same application, the higher it is located in the pyramid, the more desirable it would be to use. Generally, it is easier to start at the base of the biomass pyramid, but more rewards (and more efficiency) can

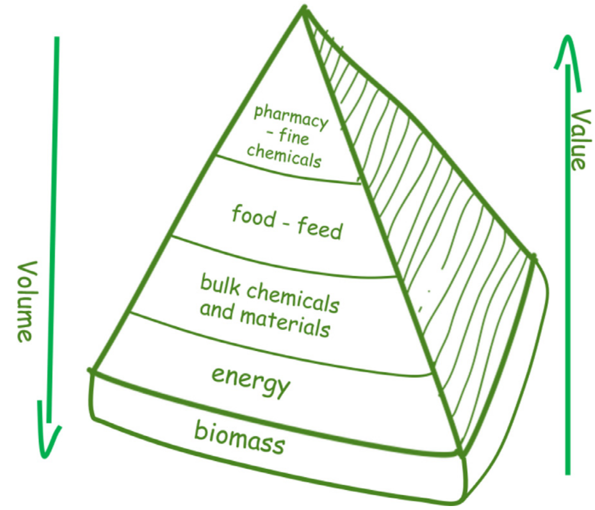

Fig. 1. CBE value pyramid
Source: The author's own illustration adapted from Stegmann et al., 2020 and Borrello et al., 2020b.

be reached by climbing to the top of the pyramid. On the other hand, using the upper part of the pyramid implies that new organisational challenges are required; such challenges are addressed in the current paper.

2.2. Supply chain coordination

A large body of literature has assessed the role of coordination among supply chain actors as an important element for value creation (Almeida et al., 2013; de Besi and McCormick, 2015) when developing new sustainable supply chains (Luthra et al., 2017; Carraresi et al., 2018). Supply chain coordination is strictly linked to the concept of interdependence among actors, with the governance of relations and transactions as crucial steps to be built in a new supply chain (Handayati et al., 2015).

Several coordination mechanisms have been highlighted to manage interdependencies aiming at improving supply chain performances. Handayati and colleagues (2015) identified four different coordination mechanisms: i) supply chain contract, ii) information sharing, iii) joint decision-making and iv) collective learning. While contracts formalise transactions for long-lasting agreements, information sharing improves the performance of a supply chain. The other two mechanisms are also relevant since joint decision-making avoids conflicts among actors and collective learning allows for the extension of the capability of actors in continuously improving (Handayati et al., 2015). All these mechanisms have been taken into consideration in the current study, some as contract attributes and others as contract configuration. To illustrate, by study design, millers were asked to express their interest in joining the hypothetical OC supply chain through a cooperative. A cooperative is a specific configuration that implies information sharing, joint decision-making, and collective learning (Grandori and Furlotti, 2006; Gil and Zanarone, 2018). A question remains related to supply chain contracts. More specifically, these contracts are conceived as formal and self-reinforcing agreements (Gil and Zanarone, 2018) that brings robust properties to the governing of uncertain, complex and, more importantly, innovative transactions that market-like transactions and informal contracts may not have (Grandori and Furlotti, 2006). Moreover, such contracts may be able to manage complex projects of supply building and are particularly relevant for the governance of innovative activities (Grandori and Furlotti, 2019). A growing number of studies have investigated contract mechanisms in biomass supply chains.

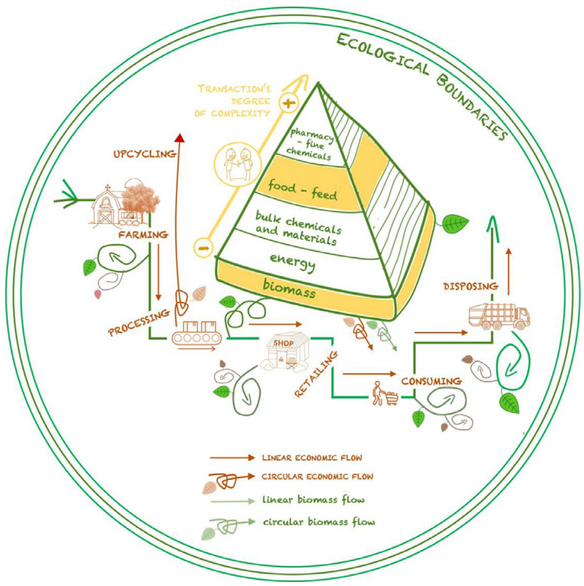

Fig. 2. The CBE and its element from a supply chain perspective
Source: The author's own illustration adapted from Rockström et al., 2009 and Donner and Radic, 2021.

For instance, Raimondo and colleagues (2018) have analysed the willingness of citrus transformers to invest in a multifunctional plant for processing citrus by-products. The willingness of farmers to convert wheat cultivations into bio-energy crops in a rural marginal area of southern Italy was investigated by Cembalo and colleagues (2014a) and by Selvaggi and colleagues (2018). All these studies have, as a common field of enquiry, the management of a new supply chain that informed our research questions.

2.3. Supply chain perspective of CBE

While the previous two sub-paragraphs provided a broad discussion on concepts and implications of CBE, as well as on supply chain coordination mechanisms, in this paragraph the two concepts are melded together providing the theoretical framework underpinning the empirical study reported in the current paper.

The framework is based on a supply chain perspective, that is illustrating main elements that might be found in most of the agri-food supply chain (Fig. 2). Starting from the outer circles, CE designs a worldview where economic activities are a subset of the ecological ones, being the latter bounded by ecological limits (Borrello et al., 2020b). Within this limit a CBE strategy is called for a resource efficiency design from farm-to-fork. This design is illustrated in Fig. 2 by means of economic (red arrows) and biomass flows (green arrows), respectively separated in linear (straight arrows) and circular (twisted arrows) flows. From farming to disposal, economic and biomass linear flows represent the backbone of a generic linear food supply chain. Fig. 2 shows that, in each step of this linear chain, economic and biomass circular flows may be activated, giving rise to cascading processes of subsequent and differentiated types of biomass reuse. Ideally, each of these reuses can generate new products for the market. Fig. 2 zoom in at the processing stage of the supply chain, where the current study is focused, showing that through cascading processes biomass is upcycled following the rules of the biomass pyramid. In the illustration, twisted arrows are decorated with leaves; this is meant to emphasize that circularity harmonizes economic and biomass supply chain flows with the planetary ecological boundaries (Rockström et al, 2009).

Secondary products and biomass are integrated in a multi-output production chain while making use of residues and wastes, in each step/ring of the chain, optimizing the value of biomass over time via cascading. Economic, social and environmental aspects may, in this way, (ideally) be optimized. The cascading approach aims at preserving, as long as possible, the resource quality by means of the bio-based pyramid. It is easier to start at the base of the biomass pyramid where transaction's degree of complexity is lower, but more rewards can be reached by climbing to the top of the pyramid where more formal coordination mechanisms are needed. CBE supply chains, indeed, show a peculiar feature of simultaneously focussing on integrating and coordinating buying companies and suppliers, stimulating cooperation among them. Specifically, better coordination among key stakeholders may represent an important pass-through to develop and sustain the supply chains over time (Tsolakis et al., 2014). Put differently, using the upper part of the pyramid, where the complexity of transactions is higher, implies that new organisational challenges are required.

3. Data and methodology

The current paragraph illustrates data and methodology implemented in the empirical analysis. It describes the survey design and the questionnaire's sections (four in total) submitted to millers (Section 3.1). The Discrete Choice Experiment (DCE) is also detailed explained reporting contract attribute description (Section 3.2), as well as the illustration of the statistical method implemented (Section 3.3).

3.1. Survey design

A large sample of millers operating in Sicily (a region in Southern Italy) were interviewed at the end of 2015 to identify factors or barriers impacting their participation in the OC supply chain and to design the most preferred set of contract attribute that might foster their involvement in the CBE supply chain.

The sample is composed of 201 Sicilian olive oil producers (millers) and it represents the regional population accounting for the 38% of the producers in the region (Ismea, 2020). Data were obtained by submitting a face-to-face survey to millers located in each of the nine Sicilian provinces, namely: Agrigento (AG), Caltanissetta (CL), Catania (CT), Enna (EN), Messina (ME), Palermo (PA), Ragusa (RG), Siracusa (SR), and Trapani (TP). Fig. 3 shows the locations of the surveyed millers within the nine provinces.

The survey questionnaire is divided into four sections and is available in Supplementary information. In the first, socio-demographic information about the entrepreneurial and structural characteristics of the firm were collected, including figures about olive processing capacity and OC production. In the second section of the questionnaire, previous participation of the firm in cooperatives, as well as previous investments and innovations adopted by the entrepreneurs, were collected. The third section of the questionnaire was dedicated to capture millers' attitudes and motivations to participate in the OC supply chain by means of the TPB constructs (Ajzen, 1991). TPB is one of the most widely adopted framework for examining any sort of human behaviour that may cover food purchases (Cembalo et al., 2019) enterprises' investment decisions (Zhang et al., 2013) or health related choices (Yang et al., 2010). Well recognizes advantages of the TPB's approach include its flexibility and the high predictive value (Despotović et al., 2019). TPB is characterized by several behavioural constructs such as attitudes, social norms, and the Perceived Behavioural Control (PBC).

The first one (*Attitudes*) is based on personal evaluations and opinions about the consequences of the decision. *Social norms* include what other people could think about one's own behaviour,

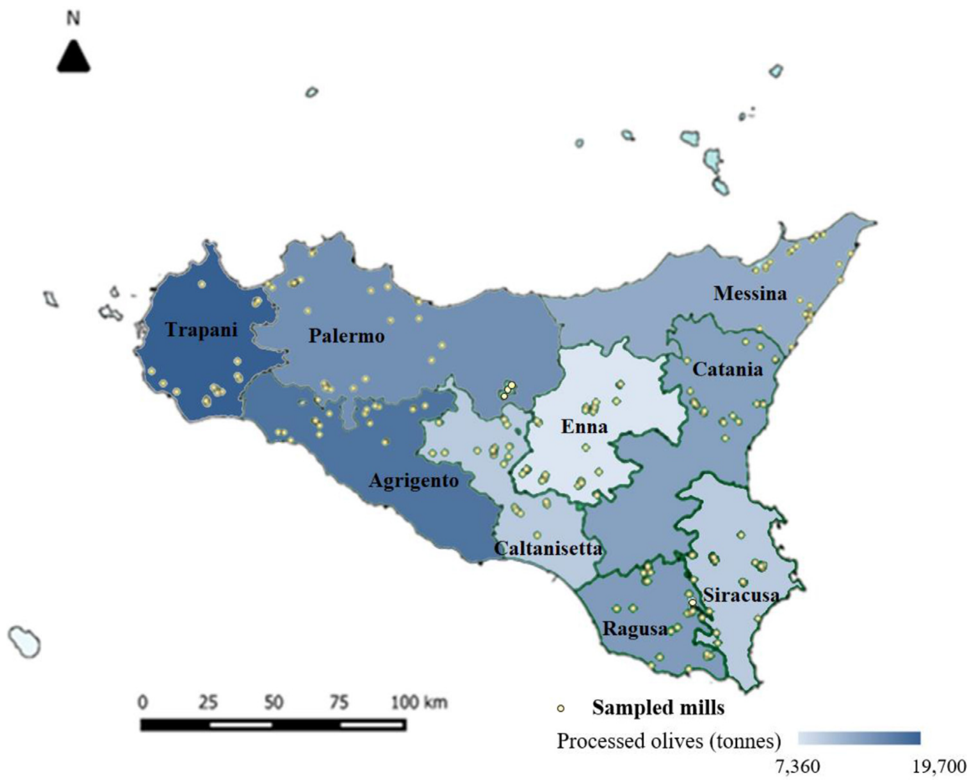

Fig. 3. The localisation of olive oil Sicilian industries (mills) participating in the study and the processed olives (tonnes) within each province.

Table 1
Description of items submitted to investigate individual motivations towards OC participation.

Item	Item description
	Attitudes
1	I think that to collaborate with other millers to valorise olive cake could generate positive effects for the society and the area where I live.
2	I think that to collaborate with other millers to valorise olive cake reduces the environmental problems.
3	To collaborate with firms for creating a feedstuff supply chain by valorising olive cake is a good idea.
4	I think that to collaborate with other millers to create olive cake supply chain for producing animal feed will increase the occupation in the area. where I leave.
5	Millers cooperation in the olive cake supply chain will produce profitability both for me and my family.
	Perceived Behavioural Control
6	In my opinion, I cannot collaborate with other millers.
7	In my opinion, I can cooperate with other millers to valorise olive cake.
8	In my opinion, I can eliminate misunderstanding with other millers.
9	***Social Norms*** My colleagues and my friends think that I have to collaborate in order to build an olive cake supply chain to produce animal feed.
10	Majority people I know and I appreciate think that I have to collaborate to build an eco-innovative supply chain.
11	How do you consider your risk propensity?

and, finally, PBC represents a subjective evaluation of the own internal and external capabilities and/or limitations that may influence the actual behaviour.

Previous literature has already implemented the TPB constructs to analyse farmers' intentions to adopt cleaner agricultural practices (Despotović et al., 2019) and their participation in collective action to improve environmental sustainability (Cembalo et al., 2014a). In total, 11 items are here used to measure TPB dimensions (Table 1): five items related to attitudes, four to PBC, and two related to social norms. A 7-point Likert scale was applied to rank each item from 1 = 'totally disagree' to 7 = 'totally agree', with the exception of the last item where the anchors were 1 ='totally risk averse' and 7 ='totally risk inclined'. Item responses were statistically elaborated by means of an exploratory factor analysis (EFA): The latter identified three principal factors corresponding to the three TPB components (attitudes, social norms, and PBC). Detailed results on the EFA are reported in Supplementary information.

Finally, section four of the survey investigated the entrepreneur's propensity to participate (PtP) in a hypothetical CBE supply chain concerning the valorisation of OC into feedstuff. Furthermore, this section included the stated choice experiment for understanding factors impacting entrepreneurs' decisions and the trade-off they operate between the characteristics of the contract mechanism.

3.2. Discrete choice experiment

Discrete choice experiments (DCEs) include a broad class of evaluation methods that are used to quantify decision makers' preferences and their willingness to trade off attributes of services or products. DCEs have been firstly developed in the 1960s by mathematical psychologists (Luce and Tuckey, 1964) and subsequently expanded by marketing researchers (Green and Rao, 1971). Being consistent with the Lancaster theory that assumes individual preferences based on the product attributes rather than on

Table 2
Selected attributes and specific levels of the proposed contracts.

Attributes	Levels definition	Quantitative range
Base Price	Current market price plus or minus a flat amount for marketing premium or fees: values are randomly generated from a normal distribution	from 32 euros to 40 euros per ton
Minimum guarantee price	Presence (1) or absence (0) of a minimum price guarantee: values are randomly generated from a binomial distribution	0 or 1
Length	Discrete values are randomly generated from a uniform distribution in the 3-10 years interval	from 3 to 10 years
Renegotiation option	Presence (1) or absence (0) of an option to renegotiate the contract terms: values are randomly generated from a binomial distribution	0 or 1
Training meeting	Presence (1) or absence (0) of mandatory participation to training meetings: values are randomly generated from a binomial distribution	0 or 1
Minimum volume of product	Presence (1) or absence (0) of minimum volume of product to being guaranteed: values are randomly generated from a binomial distribution	0 or 1

the product itself (Lancaster, 1966), DCEs have been largely used by economists since 1980s for measuring individual preferences for a diverse range of situations: Some examples include, among the others, food choices (Jaung et al., 2019), health applications (Green and Gerard, 2009), job choice (Miranda et al., 2012) and contract design (Van den Broeck, 2017).

The fourth section of the questionnaire includes the DCE carried-out in this study: The section started with the interviewer describing a hypothetical supply chain to process OC into feedstuff. A careful description of OC valorisation process, including its relevance for the Sicilian economy, was provided. The necessity to manage the proposed CBE supply chain by means of contract mechanism was also presented to the millers. In the proposed supply chain, the millers are meant to join a new cooperative for managing OC for feedstuff production. Active participation in the cooperative is needed for at least five years. Each member (millers) of the cooperative has to attend cooperative meetings at least two times per year and they have to pay a membership fee. Respondent preferences about specific contract features were investigated in detail by implementing the DCE. Respondents stated their preferences by choosing the most preferred contract among two contract schemes characterised by six attributes with varying levels. Attributes were selected through a *focus group* process: It involves the use of in-depth group interviews in which eight participants representing agribusiness management scholars (in pairs), feed producers (in groups of three) and olive oil processors (in groups of three) contributed to identify main contracts attributes. The process was held in about a two-hour session: Participants were asked to validate and to rank the attributes among those suggested by recent studies (Abebe et al., 2013; Cembalo et al., 2014b; Khanna et al., 2017; Wamisho Hossiso et al., 2017). Table 2 shows the final (first six ranked) attributes of contracts with the following relative range:

i) The OC base price, that is, the unitary price paid by feed producers to millers per OC tons. The base price accounts for the most likely market price for OC. Its average was set to be 36€, selected from a uniform distribution from 32€ to 40€.
ii) The possibility to guarantee a minimum price to millers (presence or absence).
iii) The definition of a minimum quantity of OC to provide to feed producers, with a penalty if the minimum quantity is not reached (presence or absence).
iv) The length of contract (randomly determined between 3 and 10 years);
v) The possibility to sign a new contract before the deadline of the previous one (presence or absence);
vi) The obligation for millers to take part in cooperative meetings to make joint decisions and to share information for collective learning about economic and technical aspects of the supply-chain (presence or absence).

The selected attributes, which formed the contract types at different levels, were carefully described so that respondents could make an informed choice. The experimental design follows Roe et al, (2004): it consists in presenting two alternative contracts and the opt-out option based on a random combination of the levels, with the latter assigned according to specific probability distributions (Table 2). The two contracts were shown to interviewees asking to choose the most preferred contract alternative or none (Table 3). This process was repeated three times by each respondent, so final data included (201 × 3) 603 overall stated choices from 201 millers. The randomization of the levels makes this section of the questionnaire unique to each respondent.

3.3. Statistical methods

Millers' PtP as a cooperative member in the OC supply chain was analysed by means of a Probit model, which is a widely used method to analyse dichotomic processes such as choices. While PtP represents an unobservable latent variable, the survey collected the millers' interest to participate as either yes (Y_i=1) or no (Y_i=0): More specifically, millers that refused all the three times to choose any type of contracts have been considered not interested to participate. PtP can be modelled as a continuous variable ranging from 0 to 1 as a probability that the i-th miller expressed an interest to participate, $p(Y_i=1)$. Analytically,

$$\begin{aligned} \mathrm{PtP_i} &= p(Y_i = 1) = p(-\varepsilon_i < \alpha + \mathbf{dK}_i + \boldsymbol{\beta}\mathbf{X}_i + \boldsymbol{\gamma}\mathbf{Z}_i + \boldsymbol{\tau}\mathbf{W}_i) \\ &= F(\alpha + \mathbf{dK}_i + \boldsymbol{\beta}\mathbf{X}_i + \boldsymbol{\gamma}\mathbf{Z}_i + \boldsymbol{\tau}\mathbf{W}_i) \end{aligned} \tag{1}$$

where for the i-th entrepreneur the $\boldsymbol{K_i}$ $\boldsymbol{X_i}$ $\boldsymbol{Z_i}$ $\boldsymbol{W_i}$ vectors include, respectively: The socio-demographics characteristics of the entrepreneur, the structural characteristics of the firm, previous experiences in the contract's mechanisms, and personal motivations and attitudes of the entrepreneur in terms of factor scores as calculated by EFA. Finally, F stands for the cumulative distribution function of the standardised normal distribution, and ε_i represents the error component. The model parameters include: α, the intercept, and $\boldsymbol{d}$, $\boldsymbol{\beta}$, $\boldsymbol{\gamma}$, and $\boldsymbol{\tau}$ are model coefficients to be estimated, indicating the role of each miller's/plant's $\boldsymbol{K_i}$ $\boldsymbol{X_i}$ $\boldsymbol{Z_i}$ $\boldsymbol{W_i}$ characteristics in impacting the PtP.

Millers' choice for contract alternatives were analysed by adopting the theoretical framework of the Random Utility Model (RUM) proposed by McFadden (2001) and the Conditional Logit for estimating model parameters (Train, 2009). To illustrate, by considering a group of 'C' contract alternatives shown to the i-th millers, the utility associated to the alternative c can be represented as a linear function of all $\boldsymbol{h}$ attributes and levels characterising the c contract:

$$U_c^i = h_c'\Omega + \nu_c^i \tag{2}$$

where $\boldsymbol{h_c}$ is the vector of contract attributes, $\boldsymbol{\Omega}$ is a parameters vector, and the $\nu^i{}_c$ term is the stochastic error component. The

Table 3
Example of the choice cards presented to respondents.

		Contract A	Contract B
Contract attributes	**Base price** Current market price plus or minus a flat amount for marketing premium or fees	35	39
	Minimum guarantee price Presence (Yes) or absence (No) of a minimum price guarantee	NO	NO
	Length Overall length of contract	5	8
	Renegotiation option Presence (Yes) or absence (No) of an option to renegotiate the contract terms	YES	NO
	Training meeting Presence (Yes) or absence (No) of mandatory participation to training meetings	NO	YES
	Minimum volume of product Presence (Yes) or absence (No) of minimum volume of product to being guaranteed	YES	YES

Table 4
Description and summary statistics of the explanatory variables.

Variable	Description	Mean	Std.dev	Min	Max
K: socio-demographic characteristics					
Age	Age of miller	52.23	12.85	22	88
Activity	Years of activity	17.26	10.91	1	60
Gender	0 woman; 1 man	0.76	0.43	0	1
X: structural characteristics of the mill					
Q_olives	Tons of olives processed	600.45	480.02	30	3,000
Q_oil	Tons of oil produced	97.52	80.65	5.10	540
Q_OC	Tons of OC produced	273.55	212.74	13.50	1,350
Loc.	Region areas*: 1 AG, 2 CL, 3 CT, 4 EN, 5 ME, 6 PA, 7 RA, 8 SR, 9 TP	N.A.	N.A.	1	9
Z: Previous experiences of entrepreneur					
Invest	1 if miller has invested in firm during the last 5 years, 0 otherwise	0.53	0.50	0	1
Innov	1 if miller has introduced innovations during the last 5 years, 0 otherwise	0.33	0.47	0	1
Part	1 if miller has took part in a cooperative, 0 otherwise	0.32	0.47	0	1
Contr	1 if miller has signed a supply chain contract, 0 otherwise	0.28	0.45	0	1
W: Individual motivations towards OC participation					
Att	I Factor scores - individual *attitudes* towards participation.	0	1	-2.39	1.55
PBC	II Factor scores - *PBC*.	0	1	-3.45	1.74
SocNorm	III Factor scores - *social norms*	0	1	-1.81	2.46

Note: N.A. - not available. **W** are standardized to a mean of 0 and variance of 1 being factor scores calculated by EFA. * The nine provinces have been included in the estimates as dummy variables.

model assumes that the *i*-th miller chooses the contract alternative *c* rather than *k* since it maximises his 'expected utility': $U^i{}_c \geq U^i{}_k$, where *c* and *k* alternatives $\in C$ and $k \neq c$.

In the former model, the observed choice can be modelled in terms of probability. Analytically, the probability that the *i*-th miller choses a specific contract *c* among all different alternatives C is due to the probability that the *c* alternative utility is higher (or equal) than other proposed contract alternatives: $p(U^i{}_c) = p\{U^i{}_c > \max(U^i{}_k, \ldots, U^i{}_C)\}$. Therefore, parameter estimate $\boldsymbol{\Omega}$ identifies the influence of the contract attributes on the probability that the contract is chosen, allowing for the identification of the influence of the six contract attributes on the millers' choices. Model parameters were estimated using the maximum likelihood estimator assuming conditional logit fixed parameter specifications (Amemiya, 1985).

Table 5
Previous experiences (investments, innovation, and cooperation in the last five years) (absolute and percentage frequency).

	Abs. Frequency	Percentage
Investments in the last 5 years	**106**	**53%**
Machines acquisition	*90*	*45%*
Processing and packaging	*54*	*27%*
New constructions	*47*	*23%*
Marketing	*29*	*14%*
Innovations in the last 5 years	**66**	33**%**
Participation in cooperative	**65**	**32%**
Non-structured cooperative	*39*	*19%*
Structured cooperative	*26*	*13%*

4. Results and discussion

The current paragraph ties together result with the aim of elaborating a discussion on the lessons learnt. The following two subsections reports a description of the sample (4.1) as well as results of the Probit model that focuses on determinants and barriers of millers' PtP in an OC supply chain (4.2). Section 4.3 describes results of the choice experiment, thus providing and discussing entrepreneurs' preferences towards contract attributes.

4.1. Overview of sample characteristics

Descriptive statistics (Table 4) revealed that the majority of interviewed millers are men, with an average age of 52 years, conducting their business from a minimum of one to a maximum of 60 years (average 17). The mills processed on average of 600 tons of olives during 2015 (Q_olives), producing 97 tons of olive oil (Q_oil). As for the OC production (Q_OC), the minimum quantity produced by mills was about 14 tons, while the maximum was 1,350 tons (with an average of about 273 tons). The average travel distance for disposing the OC is 87 km, with a maximum distance of 300 km and a minimum equal to zero (when the OC is disposed *in situ*).

Overall, in the last five years, 53% of the firms made investments. Specifically, many of them (45%) acquired new machines for processing and packaging (27%). As for innovation adoption, the 33% of interviewed introduced innovations in the last five years while 32% of the interviewees declared having experienced previous participation in cooperatives (Table 5).

In Table 6, the relative and absolute frequencies, per province, of millers interested in participating in the proposed OC supply chain are reported. Most of the respondents expressed interest in participating, with Trapani showing the highest score (100%) and Siracusa the lowest (55%). The causes of the differences at provincial level are unknown which motivates the need to analyse in a more systematic way this and other sources of heterogeneity in millers' behaviour.

Table 6
Frequency distribution of interviewees and their stated interest in the supply chain to valorise OC.

Province	#interviewed millers	#interviewed interested	#interviewed interested/#total interviewed %
Agrigento(AG)	22	18	82%
Caltanissetta(CL)	21	12	57%
Catania(CT)	22	13	59%
Enna(EN)	22	16	73%
Messina(ME)	25	16	64%
Palermo(PA)	25	19	76%
Ragusa(RG)	22	17	77%
Siracusa(SR)	22	12	55%
Trapani(TP)	20	20	100%
Total	201	143	71%

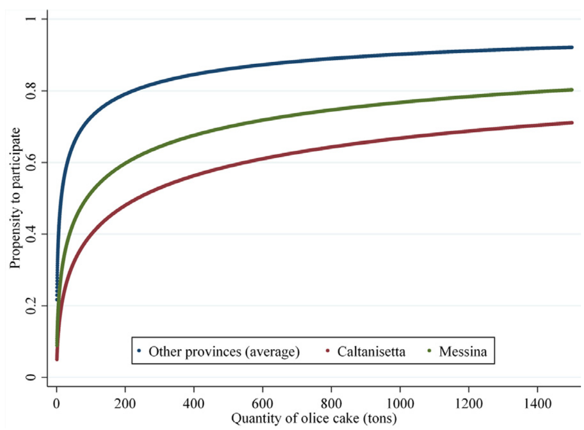

Fig. 4. Estimated relationship between millers' PtP in the OC supply chain and the OC production (Caltanissetta, Messina and other Sicilian provinces).

4.2. Participation determinants and barriers

Table 4 shows the explanatory variables of the Probit model for identifying main factors affecting the millers' PtP. Four blocks of variables have been used, representing socio-demographic characteristics of the entrepreneur (**K**), structural characteristics of the mill (**X**), previous experiences of the entrepreneur (**Z**), and, finally, individual behavioural motivations of the entrepreneur towards OC participation (**W**).

Estimates provide statistical evidence on the main aspects that influence the millers' PtP in the OC supply chain (Table 7). Variables were kept in the model if their level of statistical significance (*p*-value) was less than or equal to 0.1.

Findings show that the millers' socio-demographic characteristics (i.e. age, gender) do not statistically influence their PtP in the hypothetical supply chain. In contrast, some structural characteristics of the firm, as well as previous experiences of millers and individual motivations towards OC participation, do impact the PtP. In particular, as shown in Fig. 4, the quantity of OC produced by the firm increases a miller's propensity to join the supply chain. Indeed, the PtP rises above 50% if the firm produces at least 50 tons of OC. The higher the OC produced, the higher the PtP in the supply chain. Several studies have recognised firm size as a main driver for business cooperation (Francesconi and Heerink, 2010; Fischer and Qaim, 2012; Abebaw and Haile, 2013) since larger firms are more likely to be prone to establish contract mechanism for minimising their operating costs (Fischer and Qaim, 2014; Wang et al., 2014). In agreement with previous researchers (Abebaw and Haile, 2013; Abdulai and Birachi, 2009), our results highlight that geographical location might also influence the decision to join coordinated supply chains. Indeed,

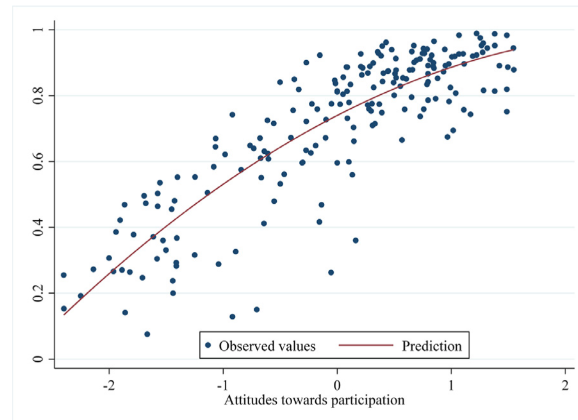

Fig. 5. Estimated relationship between millers' attitudes and PtP in the OC supply chain.

millers located in Caltanissetta and Messina provinces are less prone to participate in the proposed supply chain. This result could be due to the quantity of OC produced in Caltanissetta and Messina provinces, which is lower than the mean value (220 and 243 tons, respectively). Moreover, geographical location influences the transportation costs and, accordingly, the PtP. Several studies have shown that transportation costs are one of the main constraints for processing citrus by-product in the Mediterranean area (Vergamini et al., 2015; Negro et al., 2016; Raimondo et al., 2018). Raimondo and colleagues (2018) found that distances among plants negatively influence the propensity to process citrus by-product. Further, since the logistic infrastructures are critical in supply chain management (Wainaina et al., 2012) low endowment of infrastructures could reduce the PtP.

Probit estimates revealed that having a previous experience of millers in a cooperative decreases the PtP by 17%. This result is in line with those reported by Cembalo and colleagues (2014a) and by Zhu and Wang (2007). Cembalo and colleagues found that previous experience of farmers in cooperation negatively affects the propensity to join a bio-energy supply chain. This is probably due to a negative experience in cooperation that reduces trust in future initiatives that require a form of cooperation among entrepreneurs (Bokan et al., 2019). Moreover, the model estimates a reduction of the PtP of 12% if the interviewee has made previous investments: millers who made previous investments were less prone to join new forms of businesses (Long et al., 2016). Finally, as for individual motivations towards OC participation, neither social norms nor PBC significantly influence the PtP, and only millers' attitudes towards participation have a significant and positive effect, as shown in Fig. 5. Results are in line with those provided by Migliore and colleagues (2014) showing a positive impact of attitude on intentions for business decisions as well.

4.3. Choice experiment results

The choice experiment provides information about the entrepreneurs' preferences towards contract attributes. Table 7 reveals the results of the conditional logit model: '*Training meetings*' is the only contract attribute not statistically significant (p=0.368). Unlike previous evidence (Cembalo et al., 2014b), our findings revealed that mandatory participation in training meetings is not a relevant attribute of the contract. This result may be due to how new millers deem the contract design and, in turn, to how much informed they believe to be. Put differently, the supply chain under study does not bring any novelty deemed by millers as new. In Cembalo and colleagues (2014b), on the contrary, the supply chain under analysis concerned a new crop, namely Arundo Donax, and

Table 7
Probit model estimates—millers' PtP in the OC supply chain.

X: structural characteristics of the mill	Coef.	Std.dev	*p*-value	Marginal effect
Q_OC (ln)	0.300	0.170	0.078*	0.96
Loc. (CL)	-0.859	0.347	0.013**	-0.31
Loc. (ME)	-0.562	0.338	0.096*	-0.20
Z: Previous experiences of entrepreneur				
Invest	-0.375	0.231	0.104	-0.12
Part	-0.498	0.237	0.036**	-0.17
W: Individual motivations towards OC participation				
Att	0.717	0.114	<0.001***	0.23
Cons	-0.424	0.868	0.626	

Note: Number of observations = 201; Log likelihood = -94.93; Wald $\chi^2(6) = 51.7$; Pseudo R^2 0.21; % Correct prediction = 80.1% (****p*-value < 0.001; ***p*-value < 0.05; **p*-value < 0.1)

Table 8
Conditional logit estimates.

Variables	Coef.	Std. dev.	Z	*p*-value	euros equivalent (€/ton)	95% CI
Base price	0.172	0.033	5.21	<0.001***		
Minimum guarantee price	0.831	0.159	5.23	<0.001***	-4.83	[-2.31; -7.35]
Length	-0.147	0.029	-5.07	<0.001***	0.86	[1.32; 0.40]
Renegotiation option	0.562	0.171	3.29	0.001***	-3.26	[-1.12; -5.40]
Training meeting	0.156	0.173	0.9	0.368		
Minimum volume of product	-0.882	0.176	-5.02	<0.001***	5.12	[7.81; 2.42]
Opt-out	11.269	2.011	5.6	<0.001***		

Note: (****p*-value < 0.001; ***p*-value < 0.05; **p*-value < 0.1)

a new supply chain (energy production). In that case the need of information and knowledge was much greater than in this case. As for the other attributes, millers prefer short contracts with the presence of a minimum guarantee price, the possibility to extend the contract before its deadline (renegotiation option), and coherently higher prices for the OC without the requirement of a minimum volume of production. The length of contract is confirmed as a critical aspect for developing a biomass supply chain (Okwo and Thomas, 2014; Krah et al., 2018). Similarly, results highlight the importance of including the presence of a minimum guarantee price within the contract, as was also suggested by Cembalo and colleagues (2014b). This specific result highlights a potential risk perception of millers of the OC supply chain, probably due to the perishability and seasonality of the by-product. To this regard, an appropriate contract design may remove some sources of agricultural risks such as annual price fluctuation (Wainaina et al., 2012). The estimated opt-out coefficient was positive and statistically significant, showing respondents uncertainty or caution to select a specific contract.

Table 8 also shows the marginal value of the attribute, in monetary terms, of each attribute. The latter can be estimated with the widely-used ratio of the attribute's coefficient to the price coefficient. The presence of minimum guaranteed price is valued -4.8 €/ton: Producers are willing to give up 4.8 € of the base price that they will be paid per OC ton in order to get the term of minimum guaranteed price in the contract. At the same time, millers were willing to accept about 5 €/ton for including the clause about the minimum volume of product requirement. This might be because the high variability in olive yields (and OC, as a consequence) registered during some years. As for the renegotiation option, the marginal value is estimated to be equal to -3.3 € per ton of OC. Moreover, those interviewed would prefer to give up 0.86 € per ton of OC from the base price rather than being bound to an additional year of the contract[2].

Fig. 6 shows the positive relationship between the propensity to choose a specific contract, and therefore to participate in the OC supply chain, and the base price. A base price higher than 30 € per ton is needed to stimulate the participation of the majority of the millers ($p>0.5$). However, as shown by previous studies (Cembalo et al., 2014b), the PtP decreases if the clause for the minimum volume of the product is included in the contract. This could also be due to the typical fluctuations of olive production. Accordingly, removing the clause for the minimum volume of product could be helpful for increasing the involvement of millers in the supply chain.

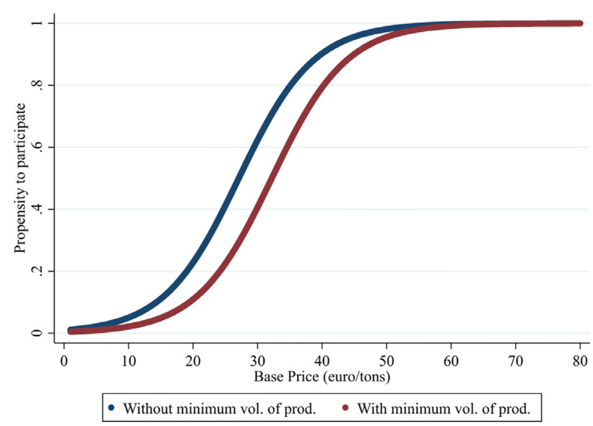

Fig. 6. PtP as a function of base price and the presence or absence of a minimum volume of production (olive cake).

Finally, 29% of interviewees declared that they were not interested in any of the proposed contracts. Table 9 summarises the motivations of such decisions. Economic motivation prevails, since most of them stated that the contracts provided were not convenient (82%) and 76% stated that 'no price is high enough for changing' the current allocation of the OC. In addition, 45% of the entrepreneurs think that, in these conditions, OC valorisation cannot be considered a strategic activity for their business, while 38% complained about the length of the contract. Moreover, a consistent percentage (62%) among those not interested stated that the proposed contracts would be profitable only for animal feed companies, which could gain too much power, while some millers

[2] Mixed logit estimates provide similar results and are available on request by the authors.

Table 9
Motivations for respondents that have chosen no contract for any choice (percentage).

Statement	Does not reflect at all→Reflects perfectly					
	1	2	3	4	5	Mean
None contract is convenient	7%	0%	2%	9%	82%	4.60
Olive cake valorisation is not a valid option for mill	9%	17%	7%	22%	45%	3.77
The contract's duration is too long	7%	5%	29%	21%	38%	3.77
Contracts are convenient only for animal feed company	5%	3%	10%	20%	62%	4.29
Animal feed company could get too much power	9%	5%	19%	26%	41%	3.86
Distrust in local millers to abide by contract term	14%	9%	31%	17%	29%	3.39
No price is convenient enough for changing	5%	0%	10%	9%	76%	4.50

(29%) stated that they do not trust cooperation with other entrepreneurs.

5. Conclusions

The current study proposed and tested a governance mechanism to manage a by-product supply chain within the CBE strategy. A case study approach was followed for a hypothetical, though realistic, CBE supply chain located in Sicily (Italy). Two research questions were tackled: 1. identifying the main factors affecting the decision of a representative sample of Sicilian millers to take part in the CBE supply chain, and 2. assessing millers' preferences for contract attributes. Based on a stated choice experiment, a Probit model and a conditional logit model were implemented to reach the first and second aim, respectively.

One relevant result regard barriers and enablers affecting participation. Study findings suggest that the available quantity of OC, as well as the personal attitude of millers, positively influence the participation in a CBE supply chain. Conversely, previous experiences (investments and cooperation) of millers discourage their willingness to participate in the proposed supply chain. Furthermore, our results indicate that the participation rate varied according to the geographical location of the firm.

Several actors in the food industry are increasingly focusing on biobased valorisation of secondary productions to diversify their activities and move into the CBE sector. In Italy, as well as in many other countries, actors deal with several bottlenecks that make difficult to reach the benefits brought by the so-called green economy. Most of the times valorisation of an existing supply chain needs to start from scratch. In this respect, it becomes relevant to understand the key elements that can help design effective supply chain mechanisms, in particular how to develop and manage integration, coordination and cooperation along the chain.

Current study results help understanding the conditions under which a supply chain can benefit of the environment brought by Governments within the sustainable development goals. Even though the CBE has the potential to improve the sustainability of supply chains, transitioning towards a new organisation model is not trivial. Social aspects, cascading, product design, and aspects related to product use must be represented. This is why moving towards a CBE supply chain needs guidance for practitioners. In the current study we focused mainly on contract design approach reaching the conclusion that there is room for formal contracts to be built. This is not a trivial outcome since formal contracts arises several issues that relates to decision-making processes. To illustrate, while companies may prefer standardised contracts, our empirical evidence indicates that personalised contracts may bring to a larger participation. On the contrary, personalising contracts may be risky and costly to manage. To lower the risk related to personalising contracts, public intervention could be desirable.

This study is not exempt from limitations, which in turn can be considered as challenges for future research. First, our study is based on stated preferences, namely, answers to hypothetical, even if realistic, survey questions that may overestimate the actual PtP. Second, this paper focuses on a specific governance mechanism to be applied to a particular CBE supply chain: While a case study approach needs to be followed, since outcomes are case specific, future research could investigate different coordination mechanisms as well as exploring contract attributes in detail.

Declaration of Competing Interest

The authors declare no conflict of interest.

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Supplementary materials

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