

Making Virtue Out of Necessity: Managing the Citrus Waste Supply Chain for Bioeconomy Applications

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Abstract

Efficient use of agricultural wastes and by-products, basically transforming waste materials into value added products, is considered as pivotal for an effective bioeconomy strategy for the rural development. To this scope, citrus waste management represents a major issue for citrus processors but, at the same time, it embodies a potentially unexploited resource for the rural sustainable development. This study focuses on analyzing the current management of citrus waste in South Italy and identifying the determinants and barriers that may affect an entrepreneur's choice on the destination of citrus waste. Citrus processors' preferences about the contract characteristics needed to take part in a co-investment scheme have been investigated. Both analyses are preliminary steps to design an innovative and sustainable citrus by-product supply chain. Results show that the distance between the citrus processors and the citrus by-products plant is one of the main criteria for choosing alternative valorization pathways. Moreover, the required guaranteed capital, the short duration of the contract, and low risk are contract scheme characteristics that improve entrepreneurs' willingness to co-invest in the development of a citrus waste multifunctional plant.

Keywords

Bio-economy; Agricultural by-product; Horizontal coordination; Contract mechanism; Choice model; Waste valorization

1. Introduction

The increasing awareness about more sustainable uses of natural resources and the shift to a resource-efficient economy (Testa et al., 2016; Kumar et al., 2015; Tilman et al., 2011; Iakovou et al., 2010) are stimulating policy initiatives and institutional processes towards the development of bioeconomy strategies (Hagemann et al., 2016). Bioeconomy is aimed at “making virtue out of necessity” (von Braun, 2013). More formally, a recent definition of bio economy refers it to economic, environmental, and social activities, combined with the production, yield, transport, pre-processing, conversion, and use of biomass, to produce bioenergy, bioproducts, and biofuels (Hess et al., 2016). Moreover, bioeconomy has been identified as a strategic lever, both at the European and international level (European Commission, 2012; McCormick & Kautto, 2013), for job creation in rural and urban areas and for the reduction of dependence on energy from fossil fuels, thereby promoting, at the same time, environmental and economic sustainability (European Commission, 2012).

In this context agricultural wastes and by-products are gaining a renewed importance, since they could be considered part of an effective bioeconomy strategy by transforming waste materials into value added products (Mirabella et al., 2014; Scarlat et al., 2015; Oldfield et al., 2016). Indeed, new sources of economic value for the participants in the supply chain as well as social benefits for society (Boehlje & Bröring, 2011) can be unlocked by using waste materials for producing valuable novel products (Laufenberg et al., 2003). This study focuses on the valorization of citrus waste (known in Italy as *pastazzo*) as a useful example for generating new market and non-market values (Chinnici et al., 2018).

Pastazzo management represents a major issue for citrus processors due to the high costs incurred for pre-treatments before its disposal (Ledesma-Escobar & de Castro, 2014; Sharma et al., 2017) but, at the same time, *pastazzo* embodies a potential unexploited resource for the rural economy. Some technical background is needed to illustrate this. Citrus fruits, specifically oranges, lemons, limes, grapefruits, and tangerines, are among the most cultivated fruits globally (Lin et al., 2013). The global volume of citrus processed every year is about 31.2 million tons (BP, 2012), 50-60% of which is waste; that is, *pastazzo* (Wikandari et al., 2015; Sharma et al., 2017). *Pastazzo* is mainly composed of water (75–85%), mono- and disaccharides (6–8%), and a limited level of oils in the peel waste (Valenti et al., 2016). However, the essential oils also represent a potential risk to the environment if not appropriately disposed of (Mamma & Christakopoulos, 2014; Taghizadeh-Alisaraei et al., 2017; Sharma et al., 2017).

To date, several technological innovations have been developed to valorize *pastazzo*, and these are mainly aimed at converting potential environmental hazards and economic issues (Wikandari et al., 2015) into a valuable resource. Some of these approaches consist of pectin extraction (Pourbafrani et al., 2010), dietary fiber extraction (Fernández-López et al., 2004; de Moraes Crizel et al., 2013) biogas production (Calabró et al., 2016), ruminant feeding (Bampidis & Robinson, 2006) and essential oil (particularly D-limonene) extraction (Lin et al., 2013). In this regard Vergamini and co-authors (2015) have demonstrated the possible profitability of producing innovative products obtained by processing citrus by-products in the Mediterranean area. However, that research was only a simulation study. To transfer the technology from the lab to the real market, it is necessary for governments to support strategies and mechanisms that bridge research and industry, thereby fostering collaborative R&D schemes between the involved

stakeholders (Roberts et al., 2015; Mohan, 2016). For example, systemic problems hold up the adoption of renewable energy technologies (Negro et al., 2012; Popp et al., 2016). Moreover, massive financial investments are required by the involved stakeholders to foster the industrial adoption of innovations (Vergamini et al., 2015), but this cannot be performed without first understanding and then removing the barriers to the adoption and diffusion of the technological innovations (Surendra et al., 2014; Vergamini et al., 2015; Long et al., 2016). Adoption of disruptive innovations often needs a structural reorganization of the supply chain. During the last decade several studies analyzed factors that affect green and sustainable supply chains implementation (Zhu et al., 2007; Shang et al., 2010; Tseng & Hung, 2014; Agi & Nishant, 2017). One of the main barrier to technology adoption is the lack of cooperation/coordination among the stakeholders within the new supply chain (McCormik & Kaberger, 2007; Cembalo et al., 2014).

A contracts mechanism can be considered as an effective way to achieve supply chain cooperation and coordination, since it delivers flexibility by promoting participation (Abebe et al., 2013; Cembalo et al., 2014; Handayati, 2015). A preliminary investigation of some relevant contract attributes is crucial to foster cooperation among the stakeholders and to share the risk of the investment among the participants involved in a new and eco-innovative supply chain (Cembalo et al., 2014), thereby decreasing the risk and uncertainty of the adoption of the innovation (Wamisho Hossiso et al., 2017).

With this in mind, the first aim of the present study is to focus on analyzing the current (status quo) waste management of *pastazzo* in the Sicily region. By means of the statistical analysis of data acquired in Sicilian citrus plants in 2015, the determinants and barriers that influence an entrepreneur's choice of how to dispose of *pastazzo* are investigated. Secondly, we analyzed the preferences of citrus processors with regard to the contract

attributes needed to promote cooperation within an investment opportunity. At the same time, we identified the potential barriers to the implementation of a multifunctional plant to enable full valorization of *pastazzo* into valuable by-products.

Sicily is the regional leader in Italy for citrus cultivation (ISTAT, 2016)¹. Processing citrus by-products in Sicily via a multifunctional plant could provide the solution to two main issues: i) low returns from citrus cultivation and consequently its abandonment, and ii) the environmental problem associated with *pastazzo* management (Cerruto et al., 2016). Nevertheless, an innovative multifunctional plant is costly and risky since the adoption of technological innovations is strongly required. It is worth pointing out that the choice of a specific bioproduct technical solution has to be made on a case-specific base. A multifunctional plant, which will be illustrated later, may represent one of the most effective solutions available in Sicily.

The current study's innovation resides in the knowledge presented of the contract attributes required to manage the coordination and cooperation of the stakeholders involved in *pastazzo* management in Sicily. This is relevant because, although most chains are based on agreements between two or more of the participants, the case in hand shows the peculiar features of coordinating the citrus producers (suppliers) and stimulating coordination/cooperation among them.

2. The hidden value of citrus by-products

¹http://agri.istat.it/sag_is_pdwout/jsp/GerarchieTerr.jsp?id=15A|21A|31A&ct=506&an=2016

The dry portion of *pastazzo* (about 15–20%) includes mono- and disaccharides (glucose, fructose, and sucrose; about 6–8%) and polysaccharides (pectin, cellulose, and hemicellulose; about 1.5–3%), and it is characterized by a significant presence of essential oils that are composed in particular of D-limonene (about 83–97%) (Bicas et al., 2008)².

Pastazzo also contains functional nutrients, such as flavonoids, bitter principles (limonin, isolimonin), carotenes, vitamins (ascorbic acid, Vitamin B complex, carotenoids), and important minerals such as calcium and potassium (Ammerman & Henry, 1991; Valenti et al., 2016).

Recently, citrus peel residues have attracted the attention of scholars and industry in light of their potential uses. Indeed, several studies have highlighted the importance of citrus waste valorization, both for enhancing economic competitiveness (e.g., by reducing disposal costs) and for addressing potential environmental hazards (Tripodo et al., 2004; Vergamini et al., 2015; Sharma et al., 2017). The oils contained in citrus peel waste inhibit bacterial and yeast activities, thereby decreasing the rate of decomposition (Sharma et al., 2017). Hence, the direct disposal of citrus waste may generate several environmental problems if the waste if not initially treated to extract the oils component.

Several innovations have been developed during the past few years for valorization of the *pastazzo* market (Demirbas et al., 2011; Wikandari et al., 2015), and the extraction of pectin has been one of the most promising. Pectin is a polysaccharide that is commonly contained in fruits and it is widely used by the food and chemical industries (Pourbafrani et al., 2010; Bae et al., 2016). Recently a novel method was developed to increase the pectin yield from citrus peels. By using this method about 39 kg of pectin can be produced

² The relative composition may vary according to several factors, including the growing conditions, variety, and climatic situation (Kale & Adsule, 1995).

per ton of wet citrus waste (Pourbafrani et al., 2010). Many components of citrus by-products that are made up of polysaccharides and lignin could be used to create functional foods, especially dietary fiber (Marín et al., 2002; Asp, 1987). Indeed, dietary fiber from citrus by-products has a high content of cellulose and minor concentrations of lignins, pectins, and hemicellulose (Fernández-López et al., 2004); this provides a higher portion of soluble dietary fibers than wheat bran (Gorinstein et al., 2001). Moreover, the fibers from citrus waste include bioactive compounds such as flavonoids and C-vitamin, which have antioxidant power (Fernández-López et al., 2004). Because of the above-mentioned characteristics, a dietary intake of fibers from citrus by-products may help to prevent fiber deficit in the human diet (Fernández-López et al., 2004). Furthermore, food scientists suggest that orange fiber could be considered a good alternative to fat in ice cream since its functional properties reduce about 70% of ice cream's fat (de Moraes Crizel et al., 2013).

As well as human nutrition, citrus by-products can also be used as feedstuff (Grasser et al., 1995), thereby reducing the competition for land use between food and feed production (Bampidis & Robinson, 2006). The possibility of introducing citrus by-products for ruminant nutrition is due to both the availability of soluble fibers and the ability of ruminants to ferment a large quantity of fibers (Grasser et al., 1995). Citrus pulp can be given to ruminants as a fresh product or as silage, even if citrus pulp is usually fed in its dehydrated form (Bampidis & Robinson, 2006). Citrus molasses and citrus sludge are also used as part of a livestock diet. The former can be a source of feed energy for cattle (Wing et al., 1988), while the latter could be considered to be feedstuff since it has abundant amino acid components (Coleman & Shaw, 1977).

Citrus waste shows a great potential for biofuel and biogas production (Martín et al., 2013). The biogas yield for each ton of citrus by-products is currently about 87.6 Nm³ (Su et al., 2016; Boluda-Aguilar & López-Gómez, 2013), depending on different factors such as the citrus variety, temperature, pH, and microbiological characteristics of the biomass (Patinvoh et al., 2017). In this regard, several orange producing countries, including oil producers such as Iran, are strongly committed to using citrus to produce biogas and as a bioenergy source (Torquato et al., 2017; Taghizadeh-Alisaraei et al., 2017; Aboagye et al., 2016).

Finally, citrus waste has other minor uses. Citrus waste is a source of D-limonene, an essential oil that can be used to build chemical structures such as biosolvent, a renewable alternative to the halocarbon solvent (Kerton, 2009). D-limonene can also be used as a fragrance compound to produce adhesive terpene resins (Braddock, 1999). The high sorption capacity of citrus waste can be exploited for remediating wastewater from heavy metals contamination (Kausar et al., 2013).

Even though the potential use of citrus by-products has been shown in the literature, to the best of our knowledge only one Spanish company has developed a pilot multifunctional plant based on a cascade-type valorization approach, converting citrus waste into cattle feed pellets, essential oils, biofuels, and finally purifying the water used for the process by applying a pervaporation/condensation approach (Lin et al., 2013). The scant adoption and diffusion of this alternative is mainly due to the radical nature of the innovation needed for its implementation, which requires the development of new organizational models and structural changes to the pre-existing supply chains (Sharma et al., 2017).

3 The empirical study

3.1 Citrus by-product supply chain

The study was conducted in Sicily, a citrus production region in southern Italy, which accounts for about 60% of the citrus cultivated areas in Italy (ISTAT, 2016)³. The Sicilian coastal areas have the greatest share of production, with 40% of the total orange trees being in Catania, Syracuse, Enna, and Agrigento provinces (Valenti et al., 2017).

The Sicilian citrus industry can be categorized into small firms, generally family-run properties with one or two employees (that generally use old process systems), and medium-large companies with more than 20 employees (Cerruto et al., 2016). Citrus processing is usually organized in two steps: the first consists of a basic transformation to obtain citrus concentrates, which is the business model of the small firms, whereas successively larger firms complete the transformation and sell processed citrus products on the market (Aguglia et al., 2008; Chinnici et al., 2015).

As previously discussed, once the fruit is pressed a large quantity of fresh citrus (about 65%) waste is produced. Citrus by-products are considered a serious issue, since the high costs for disposing of citrus wastes induce opportunistic and illegal behaviors by the citrus processing industry⁴.

³ http://agri.istat.it/sag_is_pdwout/jsp/GerarchieTerr.jsp?id=15A|21A|31A&ct=506&an=2016

⁴ For instance in 2014, a police investigation named “Last Orange Operation” reported an illegal disposal of pastazzo in different Sicilian areas with citrus wastes being thrown into streams and onto private or public plots of land (without pre-treatment), thereby causing several environmental problems. <http://www.24live.it/69631-operazione-last-orange-traffico-illecito-di-rifiuti-sigilli-allacanditfrucht-ai-domiciliari-nunzio-calabro> [retrieved 24 October, 2017]

The citrus sector in Sicily is also marked by decreasing profit margins, which has caused a persistent reduction in areas under cultivation, and has made overall farming activities unviable⁵. In this context, the valorization of citrus by-products could result in extremely relevant environmental and economic benefits for the whole citrus supply chain and the farming sector in particular. Economic value for the firm and social benefits for the citizens can be generated by a multifunctional plant able to process *pastazzo* (Vergamini et al., 2015) through a cascade-type approach that achieves, at the same time, both environmental and economic efficiency (Lin et al., 2013). Following this route, *pastazzo* valorization may also reduce companies' costs for waste disposal, thereby creating economic value for the involved stakeholders and indirectly decreasing the risk of environmental problems.

However, the steps required to develop a multifunctional plant is fraught with barriers and challenges. These relate mainly to poor awareness among potential investors, small capitalization, lack of liquidity for participating firms, and the risk perception of the investment (Freeman, 2010; Schifani et al., 2016; Long et al., 2016). The direct involvement of supply chain participants in the development and management of an innovation through coordination and integration may represent a way of solving the above-mentioned problems (Handfield & Nichols 2002). Contract design has been mainly explored in the development of new bioenergy supply chains (Cembalo et al., 2016) in which different conditions have been considered, such as the price of the agricultural biomass, the length of contract, options for renegotiation, and the definition of a minimum product volume to be provided by the farmers (Cembalo et al., 2014). Thus, flexible contracts could be designed to facilitate stakeholders' cooperation within the shared

⁵ In Sicily about 33,000 hectares of the citrus production area were lost from 1992 to 2014 (Cerruto et al., 2016).

investment, thereby increasing the probability that a large number of stakeholders may take part in the development of the multifunctional plant (Schifani et al., 2016).

3.2 Empirical framework and methodology

Two different empirical models were used in this study. The first model analyzes the current destination of *pastazzo* in the Sicily region (*status-quo* analysis) and identifies the determinants and barriers of the different possible uses (biogas, pectin, or feedstuff). This analysis provides a picture of the ways by which stakeholders manage citrus by-products. Subsequently, a second analysis was conducted to investigate the propensity of citrus processors to cooperate within an investment opportunity. In the second analysis entrepreneurs were asked to take part in the development of a hypothetical multifunctional plant for citrus by-product valorization through a choice experiment. Entrepreneurs' preferences for the contract attributes were assessed by using a contingent valuation approach. More precisely, the contingent evaluation investigates how features of a contract may influence the propensity of entrepreneurs to participate in a hypothetical plant that produces several by-products of *pastazzo*. Both analyses can be considered preliminary steps to the design of an effective citrus by-product supply chain.

The *status-quo* analysis uses a discrete choice model to identify entrepreneur's motivations about actual *pastazzo* management. Let $\pi_{i,j}$ be the probability that the i -th entrepreneur faced with J -alternatives (such as biogas, pectin, and feedstuff) would have chosen the j -th alternative ($Y_{ij} = 1$). According to the conditional logit model (McFadden, 2001) the probability can be expressed as:

$$\pi_{i,j}(Y_{ij} = 1) = \frac{e^{\beta' z_{ij}}}{\sum_j e^{\beta' z_{ij}}} \quad [1]$$

where z_{ij} comprises the entrepreneur characteristics (such as age, gender, educational level) as well as alternative specific attributes (i.e., distance from the firm), whereas β is the parameter vector that can be obtained by using the maximum likelihood estimate (MLE).

For the second aim of the present study, a choice experiment approach was used to examine the stated preferences of the citrus processors for different contract attributes to facilitate and coordinate the finalization of their participation in the investment while identifying at the same time the entrepreneurs' preferences toward the existence and the attributes of any trade-offs between them.

Previous studies followed similar approaches (Roe et al., 2004; Cembalo et al., 2014, Schifani et al., 2016). Two different alternative contracts were shown to the entrepreneurs. The contract alternatives were characterized by a different composition of attributes and levels. Each contract typology consisted of four different attributes that are compatible with the specific investment. The attributes and levels were identified from the literature and by three focus groups carried out during the research. The differences between each contract's typology are based on the following factors.

Table 1. Attributes and levels of contracts

| Attributes | Level definition | | | | | Mea n | Std. dev | min | Max |
|-------------------------------------|---|--|--|--|--|----------|-------------|-----|-----|
| Risk and remuneration of investment | Random extraction from distribution, from 9% to 20% | | | | | 14.7 | 3.84 | 9 | 20 |

| | | | | | |
|----------------------|--|-----------|------|----|----|
| Capital warranted | Presence (1) or absence | 0.50 | N.A | 0 | 1 |
| Length of investment | Random extraction from uniform distribution, from 15 to 20 | 17.5 4 | 1.69 | 15 | 20 |
| Management decisions | Presence (1) or absence (0) | 0.50 | N.A | 0 | 1 |

N.A: not applicable

1. The length of the investment (from 15 to 20 years). 2. The degree of risk and profitability of the investment (annual rate from 9% to 20%). 3. The presence or absence of capital invested and the amount that is warranted. 4. Whether there is an ability to take part in the management decisions of the multifunctional plant (Table 1).

Analytically, considering the c -th different contract's alternatives shown to the i -th entrepreneur, the utility associated with each alternative is assumed to be a linear function composed of all the attributes \mathbf{x}_j that identify the c -th contract:

$$U^i_c = f(\mathbf{x}_j) + \varepsilon_j^i \quad [2]$$

According to the random utility theory (McFadden, 2001), the utility U^i_j can be decomposed to an observable component \mathbf{Bx}_j and an unobservable component ε_j^i . \mathbf{B} is a vector of parameters to be estimated by a conditional logit model and MLE (Amemiya, 1985).

$$U^i_j = \mathbf{Bx}_j + \varepsilon_j^i \quad [3]$$

\mathbf{B} parameters could be assessed by applying a logit model and maximum likelihood estimation (Amemiya, 1985).

3.3 Data

The data populating both the models are observational and are gathered from a sample of Sicilian medium and large citrus processing firms that produce *pastazzo* as waste. Data were collected in 2015 by submitting a vis-à-vis questionnaire to the entrepreneurs of the surveyed firms.

The survey tool was comprehensive and included information regarding: a) the socio-demographic aspects about the entrepreneur and the main company's structural characteristics; b) the current waste management system, and c) the choice-based contingent valuation about the potential contract's typologies between the firm and the other private (or public) company.

The overall population of the medium and large Sicilian citrus processing firms comprises a total of 21 enterprises. A sample of 11 enterprises successfully completed the survey (Figure 1).



Fig. 1. Spatial localization of the eleven surveyed firms.

Based on the collected data, about half of the plants are located in Messina (54%), and they are frequently conducted by a male (81%) with an average age of 54 years (42 the youngest entrepreneur and 74 the oldest entrepreneur). The average company has been running for 22 years with the youngest being eight years old and the oldest 47 years old. With regard to the specific citrus transformed, all the firms transform oranges but with some differences: 54% of the companies transform only oranges and lemons, whereas the remaining 46% also transform other citrus fruits. In 2015 each firm processed (on average) 21,909 tons of oranges to produce 8,891 tons of orange juice and 12,791 tons of *pastazzo*. In most cases the orange by-products are used to produce biogas (45%) or are converted into pectin (36%), while two plants transform their *pastazzo* to produce animal

feed. In the cases where the orange by-products were not processed *in situ*, the *pastazzo* was dispatched on average about 82 km to the processing firm (Table 2).

Table 2. Sample characteristics

| PLANT | PROVINCE | AGE | GENDER | YEARS | CITRUS TRANSF ^a | TRANS. ORANGE (t) | PROD. JUICE (t) | ORANGE BY-PRODUCT (t) | DISPOSAL DISTANCE (Km) | BY-PRODUCT END USE |
|-------------|----------|-----------|--------|-----------|----------------------------|-------------------|-----------------|-----------------------|------------------------|--------------------|
| 1 | Messina | 56 | M | 25 | Or-Lem-Others | 40,000 | 18,800 | 21,200 | 0 | Animal feed |
| 2 | Catania | 49 | M | 20 | Or-Lem | 15,000 | 6,000 | 9,000 | 116 | Biogas |
| 3 | Palermo | 72 | M | 47 | Or-Lem | 10,000 | 4,000 | 6,000 | 128 | Biogas |
| 4 | Messina | 53 | F | 20 | Or-Lem | 40,000 | 16,000 | 23,000 | 20 | Pectin |
| 5 | Messina | 49 | M | 10 | Or-Lem | 12,000 | 4,500 | 7,000 | 3.6 | Pectin |
| 6 | Catania | 54 | M | 18 | Or-Lem-Others | 30,000 | 12,000 | 18 | 130 | Biogas |
| 7 | Messina | 74 | M | 35 | Or-Lem-Others | 23,000 | 9,000 | 14,000 | 110 | Biogas |
| 8 | Messina | 59 | F | 20 | Or-Lem | 25,000 | 10,000 | 14,000 | 105 | Biogas |
| 9 | Messina | 43 | M | 15 | Or-Lem-Others | 8,000 | 3,000 | 5,000 | 67 | Pectin |
| 10 | Catania | 42 | M | 8 | Or-Lem-Others | 25,000 | 9,500 | 15,500 | 0 | Animal feed |
| 11 | Palermo | 47 | M | 20 | Or-Lem | 13,000 | 5,000 | 8,000 | 222 | Pectin |
| Mean | | 54 | | 22 | | 21,909 | 8,890 | 12,790 | 81.96 | |

^aOr: orange; Lem: lemons

4. Results and discussions

4.1 Status-quo analysis

The first model aimed to analyze the determinants and barriers related to the current entrepreneur's choice on the *pastazzo* way of valorization (such as biogas, pectin, or feedstuff). Variables that were not significant at the chosen level ($p < 0.10$) were not accounted for in the adopted models.

The results in Table 3 clearly show that some aspects significantly influence the entrepreneur's choice on the final destination(s) of the citrus by-products. The distance between the companies and plants to transform the *pastazzo* negatively affects the chosen alternative.

Table 3. Determinants of current destination of *pastazzo* – conditional logit estimates

| Variable | Coef. | Std. err | t-stat | p-value |
|--|--------|----------|--------|---------|
| <i>ln</i> (distance) | -1.09 | 0.39 | -2.78 | 0.005 |
| Biogas \times age | 0.13 | 0.03 | 4.5 | 0 |
| Pectin \times <i>ln</i> (return past) | -14.37 | 3.94 | -3.65 | 0 |
| Feedstuff \times <i>ln</i> (return past) | -5.80 | 2.60 | -2.23 | 0.026 |

Wald $\chi^2(5) = 44.17$; p-value < 0.01; $R^2 = 0.51$ (pseudo)

Distance can be considered a proxy of transport cost and represents a critical barrier (as shown in Figure 2) for processing the *pastazzo*; thus, it directly influences the disposal costs. Accordingly, our results confirm that the transportation costs of citrus waste are among the main constraints for *pastazzo* valorization in the Mediterranean area (Vergamini et al., 2015). Indeed, the study of Negro and coauthors (2016) has demonstrated that the distance from the juice production plant to the biogas production plant negatively influences ethanol production from citrus by-products by increasing the transport costs (Zema, 2017). The current low economic return of citrus by-products increases the quantity of *pastazzo* wasted per year and thereby causes environmental issues (Taghizadeh-Alisaraei et al., 2017) that inhibit economic and social value creation. Hence, to reduce costs and increase the

economic return, it is critical to minimize the costs of transport (Zema, 2017) by reducing the distance between the site where the fresh fruits are processed and the site where the *pastazzo* is transformed.

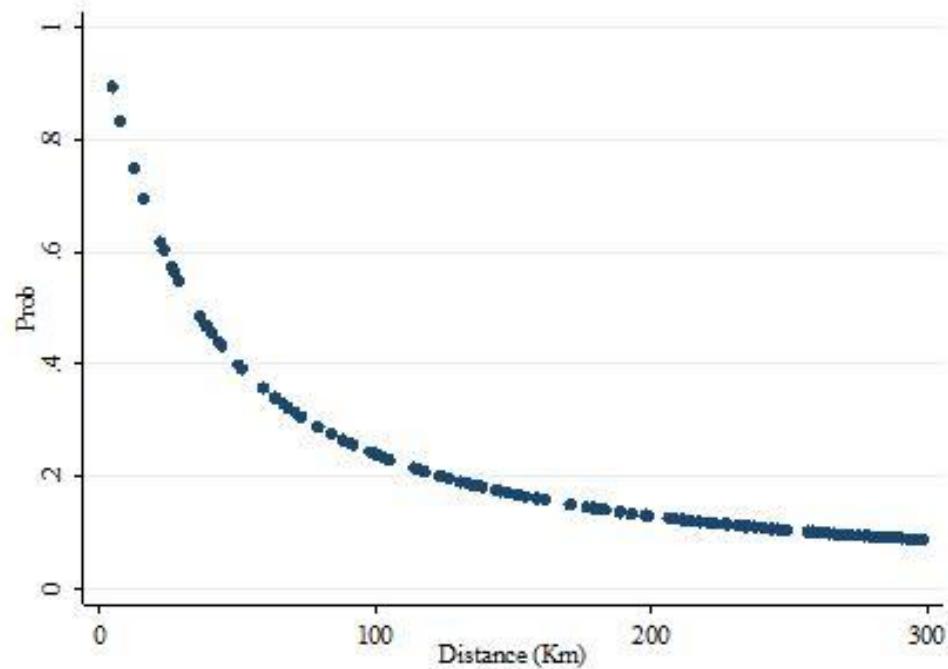


Fig. 2. The relationship between the probability of the entrepreneur choosing a specific site and the *distance* of the site.

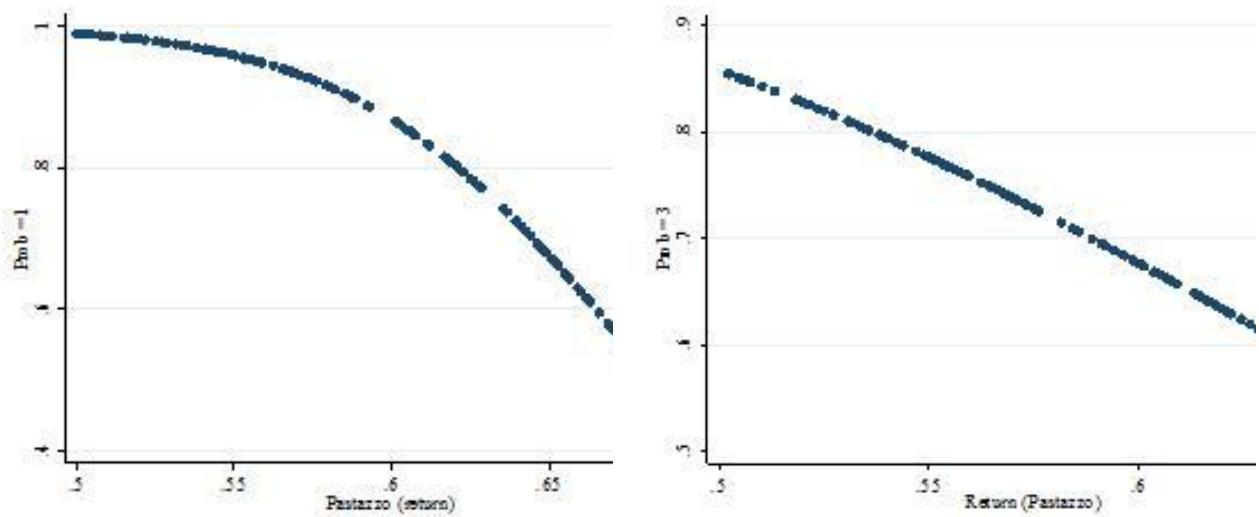


Fig. 3. The relationship between the probability of the entrepreneur choosing *pectin* (left) or *feedstuff* (right) and the *pastazzo* return.

The return from *pastazzo* negatively influences the transformation of the orange by-products into pectin and feedstuff (Figure 3), but it positively influences the biogas way of valorization. The return from citrus by-products in pectin is lower than the returns from biogas or feedstuff production. Indeed, one ton of wet citrus waste produces about 38 kg of pectin (Pourbafrani et al., 2010). The percentage is more than 4% if one deals with the dried citrus waste (Rezzadori et al., 2012). Current research has shown a new technical process that increases the pectin yield from ~40% of wet citrus waste to 58% (Satari et al., 2017). The return from *pastazzo* in bran production for animal feed is more than it is for pectin production (Rezzadori et al., 2012). However, the dehydration of the citrus waste and the pelletizing process to produce animal feed require a lot of energy, which indirectly reduces the profitability of *pastazzo* to feed ruminants (Negro et al., 2016). The willingness to transform *pastazzo* is positively influenced by the return from biogas production because the return from the use of the citrus waste in biogas production is higher than it is for other similar agricultural by-products (Su et al, 2016). Furthermore, the transformation of citrus by-products into biogas increases with the age of the entrepreneur. The older entrepreneurs seem to prefer transforming *pastazzo* into biogas rather than pectin or feedstuff products. Pectin production from citrus waste is a relatively new route. During the past decade several studies have investigated technology innovations to optimize the pectin yield (Kim et al., 2004; Satari et al., 2017). The innovative process and the low return from pectin production could represent a huge barrier even if there is a large demand for pectin in the market (Bae et al., 2016).

4.2 Preferences for different contract attributes

With regard to the second aim of the study, Table 4 sets out the entrepreneurs' preferences about the contract attributes, which aim to enhance the propensity of the citrus by-product producers to co-invest in a multifunctional plant for *pastazzo* transformation. Four rounds were carried out with each citrus processor. In each round two contract alternatives with specific levels for the considered

attributes were proposed to each interviewee; the entrepreneurs could choose one of the two proposed contract alternatives or none. Overall, a total of $44 = 11 \times 4$ choice events were generated within our sample (n=11).

Table 4. Preferences towards contract attributes – conditional logit estimates

| Fixed parameters | Coef. | Std. Err. | Z | P>z | Odds ratio |
|---|--------|-----------|--------|-------|------------|
| Risk and remuneration of the investment | -0.150 | 0.090 | -1.670 | 0.095 | 0.861 |
| Guarantee capital | 4.037 | 1.877 | 2.150 | 0.031 | 56.681 |
| Length of investment | -0.207 | 0.114 | -1.820 | 0.069 | 0.813 |
| Management decisions | 1.209 | 0.772 | 1.570 | 0.117 | 3.349 |

The estimates (Table 4) pointed out that “management decisions” is the only contract attribute that is not statistically significant, since the estimated coefficient is not significantly different from 0 (*p*-value > 0.10). In other words, according to the interviewed entrepreneurs, to be explicitly involved in managing the decisions at the plant (Kopecka et al., 2012) does not constitute a critical aspect of their decision to co-invest. This is probably due to the lack of trust in their management power or to the recent sustainable perspective in agro supply-chain management, in which the decision-making process has become more complicated due to the simultaneously involved economic, environmental, and social aspects (Borodin et al., 2016; Yakovleva et al., 2012; Hall et al., 2012).

Some contract attributes considered in this analysis are significant, such as the risk and the remuneration of the investment, the length of the investment, and the guarantee of the invested capital. Our outcomes emphasize the role of risk aversion (Barham et al., 2014) in affecting managerial decisions, since the interviewees prefer a short investment time frame with low risk and consequently a low remuneration on the invested capital.

In terms of the risk perception, the results are in line with previous studies (del Río Gonzalez, 2005; Johnson, 2010) that regard the risk perception as one of the most important barriers to the adoption

of innovation. Indeed, the financial cost due to a high initial investment increases the risk perception, and it represents “the core barrier” of the pro-environmental innovation adoption (Long et al., 2016). The financial risk perception in co-innovation systems is associated with the direct investment risk and the opportunity cost of the investment (Abhari et al., 2017).

The age of the interviewees (on average more than 50 years old) may also explain the low risk propensity, since risk aversion increases with the age of the entrepreneur (De Paola, 2010). Past studies have pointed out a delay in the investments due to risk aversion (Foster & Rosenzweig, 2010; Knight et al., 2003; Chronopoulos & Lumbreiras, 2017). A thorough examination of the available technologies is necessary to valorize agricultural waste and the connected risk for each of them (Broitman et al., 2017), since technological uncertainty may prevent investments turning into innovation (Chronopoulos & Siddiqui, 2015).

The preferred short length of the contract underlines the high-risk aversion that is also evident from the required guarantee on the invested capital; this seems to be the attribute that most influences entrepreneurs’ choices. Cembalo et al. (2014) obtained similar results about the duration of contracts by investigating farmers’ preferences in a new bio-energetic supply chain.

Overall, the results from our study are completely in line with those of Schifani et al. (2016), who demonstrated that farmers’ propensity to join a collective investment (regulated by contract schemes) was positively related to the presence of an option that safeguards the capital invested and was negatively related to the length of investment and a lower degree of risk (together with a lower long-run return). Figure 4 confirms the existence of the same relationship in our case and corroborates the negative impact of the risk and the remuneration of the investment on the probability that the entrepreneur would take part in the investment, whereas the guarantee investment option increases significantly the likelihood of the entrepreneur investing in the multifunctional plant.

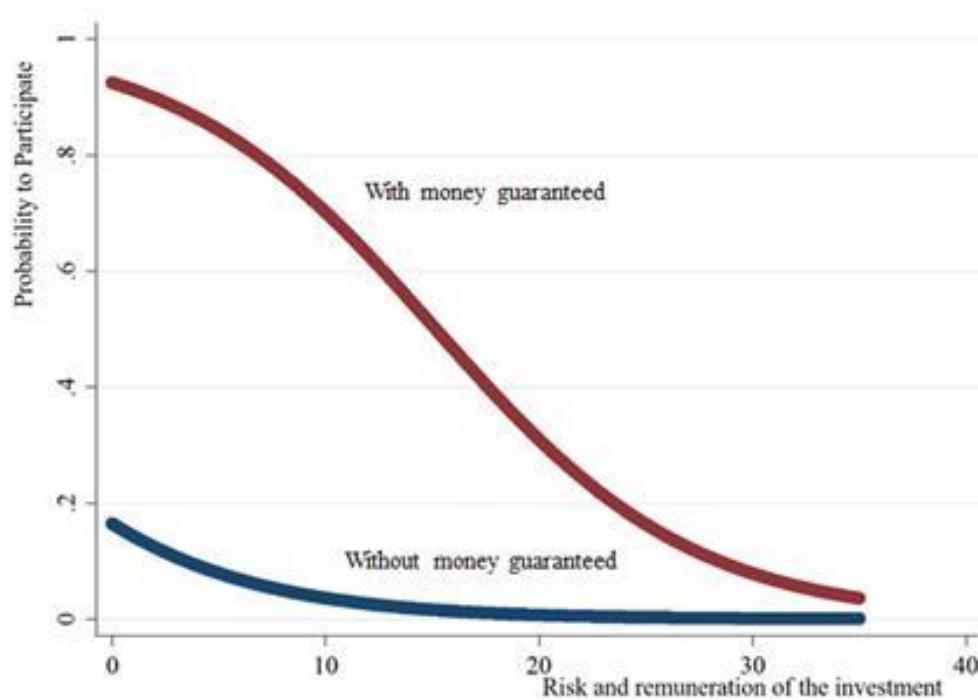


Fig. 4. The influence of risk, the remuneration from the investment, and the presence of a guarantee of the money on the entrepreneur's probability of investing.

5. Concluding remarks

The adoption and diffusion of technological innovation for *pastazzo* valorization may be viewed as an effective bioeconomy strategy for solving both economic and environmental issues (Wikandari et al., 2015; Taghizadeh-Alisaraei et al., 2017). Even though the technical feasibility of processing *pastazzo* is increasing globally, research about the adoption of technology and implementation in bioeconomy supply chains is still relatively scarce.

It is critical to understand the factors that could influence participation in the implementation of a multifunctional plant to process citrus by-products in order to improve the co-innovation; that is, the common vision and common goals shared by the participants involved in the supply chain (Abhari et al., 2017).

This study has firstly investigated the determinants and barriers affecting an entrepreneur's choice on the current *pastazzo* destination (biogas, pectin, or feedstuff). Secondly, we have investigated citrus processors' preferences about the contract characteristics needed to take part in a cooperative action for the realization of an industrial plant for *pastazzo* valorization.

This study has some limitations: the small sample of investigated companies is a consequence of a very limited population of medium and largest citrus processors. Small citrus processors were excluded from the analysis, since their limited capitalization could act as an insurmountable barrier to the entry of investors.

Nevertheless, the outcomes about the first and second aims of the study may be helpful for the implementation of a cascade-type valorization for *pastazzo*. The distance between the citrus companies and plants to transform citrus by-products decreases the current propensity to process them. As a consequence, a multifunctional plant should be as close as possible to the companies to enhance the entrepreneur's willingness to valorize *pastazzo* at an industrial level. Furthermore, the return from citrus by-products negatively affects the orange by-product transformation into pectin and feedstuff. Moreover, the probability that orange *pastazzo* will be transformed into biogas is positively correlated to the age of the entrepreneur. This implies that the return from each alternative encompassed in the cascade-type approach, such as cattle feed pellets, essential oils, and biofuels production, may influence the propensity to invest in the multifunctional plant.

Since the likelihood of committing current *pastazzo* to biogas production increases if the entrepreneur is not young, the age of the citrus transformer could also influence the level of participation in the proposed horizontal coordination. Moreover, the required guaranteed capital, the short duration of the contract, and the low risk are contract scheme characteristics that improve entrepreneurs' willingness to co-invest in the development of a citrus waste multifunctional plant.

Future research may improve the analysis by investigating the personal attitudes to the collective action of the involved stakeholders. This could be important in order to identify other potential determinants and barriers for by-product supply chain creation. Moreover, the investigation of citrus

producers' propensity to be directly involved in the co-investment represents an important feature to be analyzed. Improvement of the involvement of all the stakeholders could foster the development of a new/innovative by-product supply chain, thereby enhancing the implementation of bioeconomy strategies.

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