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Bio-economy strategies: implementation and governance in developed and developing countries

PhD thesis

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INTRODUCTION

1.1 Bio-economy strategies to mitigate global problems

During the last decades, anthropogenic green-house gas (GHG) emissions due to the huge industrialization, urbanization and intensive agricultural activities (Tripathi et al., 2016) have determined a massive increase of the global warming up (IPCC, 2015). GHG emissions, generally considered one of the major reason of the climate change, could be reduced by sequestration of CO_2 and by substituting fossil primary energy resources with renewable resources (Trainer, 2010). The demand of renewable resources is thus increased limiting consequently the availability of resources for the food supply. This is particularly enhanced by the increasing demand of food (Tilman et al., 2011) related to the growing and growing increase of the world population (OECD, 2012; FAO, 2015). The awareness about the limited nature of fossil raw materials, the relative impact upon the climate change, and all factors above mentioned are stimulating adoption of bio-economy for a more sustainable future (Hagemann et al, 2016). The bio-economy has been identified as a strategic aim both at European and international level (European Commission, 2012; McCormick, 2013). The European Commission has viewed in bio-economic strategies effective tools for economic growth, for job creation in rural and urban areas, to reduce the dependence of the energy upon fossil fuels, therefore promoting at the same time the environmental and economic sustainability (EC, 2012). Nowadays, there is not a common concern about bio-economy (Von Braun, 2013). This latter is sometimes associated to sustainability (Pfau et al., 2014) and its definition has changed over the time. In 2005, the meaning attached to the bio-economy concept was the following: sustainable management and eco-efficient use of natural resources for the production of food, energy and industrial products (DG Research, 2005) by using a set of economic activities including invention, development, production, the use of biological processes, and products (OECD, 2009). Later, Fischler, the EU Commissioner for Agriculture and Rural Development, has broadened the definition of bio-economy by introducing the theme of waste management and reuse (Schmid et al., 2012). In the document "*Innovating for Sustainable Growth: A Bio-economy for Europe*", the European Commission provides a more complete definition of bio-economy:

"*it encompasses the production of renewable biological resources, and their conversion into food, feed, bio-based products and bioenergy. It also includes agriculture, forestry, fisheries, food pulp and paper production as well as some chemical, biotechnological and energy industries. Bio-economy's sectors have a strong innovation-potential due to their use of several sciences (e.g. life* *sciences, agronomy, ecology, food sciences and social sciences), enabling industrial technologies (such as biotechnology, nanotechnology, engineering, information and communication technologies) local and tacit knowledge*" (European Commission, 2012).

This definition introduces some new concepts such as innovation and the possibility of replacement of fossil fuels with bio-based replacements for energy, goods and services. According to these stand points, adoption of innovations to implement bio-economy-strategies could also make possible a sustainable use of wastes and by-products, therefore providing possible solution for a wide set of environmental problems (Smeets et al., 2013). Bio-economy is in fact considered as a strategy for the efficient management of renewable natural resources and their wastes in order to produce food and /or bioenergy (European Commission, 2012). This last aspect will be introduced by several subsequent definitions of bio-economy. In fact, the bio-economy, also known as "bio-based economy" or "knowledge-based bio-economy" (Mc Cormick and Kautto, 2013), will be defined as an economic system in which the production of goods and energy depends mainly by the use of renewable resources from agriculture, such as plant biomass and organic waste (Mc Cormick and Kautto, 2013; Hagemann et al, 2016). The German Governement regards bio-economy as the use of biological resources to generate: products, processes and services by using sustainable economic systems (Bio-economy Council, 2013). One of the most recent definition considers bio-economy as the economic, environmental and social activities combined with the production, yield, transport, pre-processing, conversion and use of biomass to produce bio-power, bio-products and biofuels (Hess et al, 2016). In other words, bio-economy means making virtue out of necessity (Von Braun, 2013). The application of bio-economic strategies involves on one hand promotion of agriculture and sustainable fisheries, and on the other hand provides the use of renewable natural resources for industrial purposes, thus reducing GHG emissions and indirectly achieving the protection of biodiversity, the environment and food security (European Commission, 2012). The need to resort to the use of renewable natural resources is also determined by the increase of the demand of energy and natural resources. The amount of energy required in 2050 could reach 80% more than the energy used today (OECD, 2012). Energy production from renewable sources rather than fossil would thus be a priority for the purposes of food and energy security. Hence, bioenergy (energy generated by biological systems, Hintz et al., 2003), could become a possible bio-economic strategy. As a consequence, biomass is considered like a source of sustainable and synergetic production of food, feed bioenergy and bio-based products (Bell et al., 2014; van Dam et al., 2014), and it is also considered as the main future feedstock for chemicals and energy (Langeveld et al., 2010). The use of biomass, provided that at each stage it gains the highest possible value (de Besi and McCormick, 2015), leads to the solutions of many problems of the fossil-input-based economy, energy diversity, and climate change mitigation (Vandermeulen, 2012). However, the large production of bioenergy coming from agricultural crops could generate land competition (Arodudo et al., 2017). This latter also increases due to the larger incomes of consumers who generally tend to consume more calories (Lotze-Campen et al, 2008). Furthermore, it has to be reminded that the land is also required for infrastructure development and urbanization (Sands and Leimbach, 2003). Indeed, in the last decades, the different possible uses of land, have intensified competition for the land use (Harvey and Pilgrim, 2011). The scarce availability of land generates the direct competition between the use of biomass both for food and for non-food (de Besi e McCormick, 2015). As a consequence, biomass-based products and all different aspects mentioned above, may reduce food availability (von Braun, 2013).

In this context, for instance, the cultivation of crops for bioenergy may not correspond to a bio-economic strategy. Indeed, even if the bioenergy crops reduce the dependence of power generation from fossil energy sources, it could become an issue since the FAO denounces the scarcity of arable land (FAO, 2011). Achieving all the aims related to a bio-economic strategy (such as ensuring food security, sustainable management of natural resources, reducing the dependence upon non-renewable resources, mitigation of the climate change and promoting competitiveness, European Commission, 2012) could be possible by the production of energy and heat by agricultural by-products, thus obtaining a more efficient management of the waste-production and the development of a sustainable agriculture integrating food and energy system (FAO, 2013). Some important aims are identified in order to implement a sustainable agro-food chain, one of them, is the diffusion of wastes recycling (Beccali et al.,2010). As such, the agro-food system assumes an important and advanced role both for food/feed production and for renewable energy, since agricultural sector gives the possibility of recycling biomass generated by production processes and agro-food products (Cerruto et al., 2016).

The large amount of wastes (especially those related to the food industry) could produce: i) the loss of biomass as well as nutrients, and ii) pollution problems. In order to prevent environmental problems and the loss of biomass, biotechnology methods have been developed to recover and utilize nutrients from processing food wastes. Moreover, processing by-products might produce useful products with a higher value than the first one (Martin, 2012; Laufenberg et al., 2003) or, after biological treatment, might produce raw materials for industries or for the use as food or fodder (Laufenberg et al., 2003). In other words, it turns out that one may transform waste materials into value added products eliminating competition for the land use (Mirabella et al., 2014; Oldfield et al, 2016). To transform agricultural by-products in products with added value a massive adoption of technological innovations are required at public and farms level (Francis et al., 2017). Thus, processing agricultural by-products is mainly diffused in developed countries, where the adoption of innovations at farm level is larger than that in developing countries, due also to the more difficult access to the markets (Utz, 2007). However, to guarantee food security and simultaneously to support landscape resilience, GHG mitigation and rural livelihoods is also required in developing countries. Some literature studies emphasize that by adopting conservation agricultural practices, such as mixtures cultivation, it is possible to gain, at the same time: i) the reduction of agricultural chemical substances, ii) the improving of resilience in ecosystems (Lin, 2011), iii) the reduction of pest and diseases and, iv) the increment of yields (Regmi et al., 2016). Hence, some forms of conservation agriculture and in particular, mixtures cultivation can be considered an effective bio-economy strategy.

The present thesis investigates some bio-economy strategies implementations both in developed and in developing countries. Two of the three case studies have explored by-products supply chains in Sicily (Italy). In particular, these studies analysed some relevant contract attributes in order to identify contract characteristics preferred by actors involved (entrepreneurs and millers) in citrus by-product and olive cake (by-product of olive oil production) supply chains. Furthermore, some determinants and barriers to participate in a supply chain to valorise mentioned agricultural by-products, have been evidenced. As for the third study of the thesis, determinants and barriers to mixtures adoption in Uganda have been identified and mixtures impact on bean and banana perceived yields were measured. To implement a bio-economy strategy it is necessary to consider other important factors, such as governance, economy availability, personal and societal attitudes. The mentioned features quite influence the bio-economy supply chain performance, thus, the next paragraph discuss more in detail this aspect that is particularly relevant for the development of innovative by-product supply chains.

1.2 Determinants of bio-economy strategy implementation

Joint efforts by international Institutions, Governments and industry sectors are required to develop efficient bio-economy strategies in order to move, by means of renewable biological resources, an economy based on fossil raw materials toward a bio-economic one. In 2012 the European Commission (EC) has introduced a new bio-economy strategy (EC, 2012) in order to accomplish European needs to radically adjust its approach to production, consumption, processing storage, recycling/disposal of biological resources, and at the same time to take care of growing environmental pressures and climate change. One of the most important factor to create a reasonable and supportive policy framework for the bio-economic development is the governance.

Indeed, it is important that policies facilitate collaboration among all actors involved in a bio-economy strategy, and it also important that policy makers promote financial support for bio-based activities (de Besi and McCormick, 2015). According to de Besi and McCormick (2015), there are four main strategies to implement to develop bio-economy: i) to improve reasonability among different policy sectors by creating cooperation between government, research institutions and industry, ii) to improve communication to society on bio-based activities, iii) to support the creation of bio-product markets, and iv) to increase implementation of bio-economy strategies by means of financial and administrative supports.

The creation of coherence among policy measures is necessary for bio-economy (Loorbach, 2010). Governments play important roles in food systems, since their strategies could re-allocate food and nutrition in the context of bio-economy, thus ensuring a more efficient use of limited resources in order to obtain food security (Von Braun, 2013). The implementation of bio-economy strategies has to support, by subsidies and funding, research, innovation and commercialization of projects (de Besi and McCormick, 2015). In order to move technology from lab to market, it is necessary that government supports collaborative strategies and mechanisms to bridge research and industry (Mohan, 2016). Diffusion of new technologies is also required, but first of all, key policies have to let public sectors drive demand for innovative solutions. As such, the most important aim is to support collaborative R&D projects between industrial actors and academic institutes (Mohan, 2016). Improvement of technologies are possible by innovation policies. Innovation is a systematic activity that involves many and different stakeholders (Smits and Kuhlmann, 2004; Blackwell et al., 2008). According to the Innovation Policy Road Mapping method (Ahlqvist et al., 2012) R&D results have to link with policy making. This method assembles social and environmental analysis involving multiple actors and building a common view to create innovative policies (Ahlqvist et al., 2012). Recently, a literature study has identified five factors that influence the implementation and management of innovation processes in the bio-economy (Van Lancker, 2016). The first factor is radically new, and it consists of disruptive innovations which often lead to a structural modification of the supply chain. The second factor is the complex knowledge-base for this kind of innovation, thus, a variety of scientists- are get involved. Hence, cooperation among different actors is necessary (third factor). The fourth factor is the commercialization and adoption of both bio-based products and bio-economy strategies. The last important factor is the complex and fragmented policy schemes to strengthen new bio-economic strategies (Van Lancker, 2016).

The relationship between entrepreneurship and innovation have also largely discussed (Knudson et al., 2004), since some entrepreneurial characteristics, such as risk-takers, could positively influence the adoption of innovation (Knudson et al., 2004). Moreover, the attitude of entrepreneur to communicate his ideas to others could be useful to enhance cooperation among actors involved in a supply chain. As remarked above, it is essential to add a transformation in the mind-sets of society (de Besi and McCormick, 2015). Furthermore, sharing a common view stimulates actors to follow the long term goals (Mohan, 2016). This is a fundamental aspect to build new innovative and bio-economic supply chains. The literature highlights that an effective supply chain requires implementation of strategies to produce benefits for all the involved actors (Power, 2005). The management of an effective supply chain assumes the elimination of communication barriers and redundancies by coordinating, monitoring, and controlling processes (Kaufman, 1997).

An increase of the linkages between supply chain components is necessary for the implementation of cooperation, collaboration, and trust among actors. As a consequence information as well as technology sharing (Akkermans et al., 1999) lead to a reduction of costs, an improvement of customer services, therefore providing shared benefits for the majority of the partners (Power, 2005).

Relevant barriers toward the development of sustainable and innovative supply chain are often the same (like in the economic conditions) and include skills, institutional capacity and the coordination in the supply chain. These may be obstacles toward the expanding bioenergy and other bio-economic European supply chains (McCormik and Kaberger, 2007) as evidenced in several studies (Costello R, Finnell J.,1998; Roos et al., 1999; Rosch C and Kaltschmitt M., 1999; Turkenburg W., 2000; Sims REH., 2002). A lack of knowledge and skills of the actors involved in a bio-economic supply chain, together with a lack of institutional capacities, could suppress supply chain success (McCormick and Kautto, 2007), since the lack of experiences may discourage innovation adoption by farmers. To create bioenergy system the supply chain has: i) to be properly organized and ii) to answer to the needs of all actors involved. Furthermore, the adoption of technologies and the creation of coordination is required prior to any investment in biomass resources (Johansson TB, 2002). Possible strategies to overcome barriers (such as policy measures to develop know-how to enhance bioenergy systems competitiveness, and to build co-ordinated supply chain) have been investigated (McCormik and Kaberger, 2007). Nevertheless, a specific attention about contract, one of the most important mechanism to manage agricultural supply chain (Handayati et al., 2015), is scarce. Thus, next two studies of this thesis will consider contract mechanism as a tool to promote coordination within two different Sicilian agricultural by-product supply chain. As for the implementation of a bio-economy strategy in Uganda, determinants and barriers will be considered too.

2. CITRUS BY-PRODUCT VALORISATION

2.1 Introduction

The increasing awareness about a more sustainable use of natural resources and the shift to a resource-efficient economy (Tilman et al., 2011) is stimulating policies initiatives and development processes towards the adoption of bioeconomy strategies (Hagemann et al, 2016). Briefly, bioeconomy means making virtue out of necessity (Von Braun, 2013). More formally, one of the most recent definition considers bioeconomy as the economic, environmental and social activities combined with the production, yield, transport, preprocessing, conversion and use of biomass to produce biopower, bioproducts and biofuels (Hess et al, 2016). Moreover, bioeconomy has been identified as a strategic tool both at European and International level (European Commission, 2012; McCormick & Kautto, 2013) for job creation in rural and urban areas, for reduction of dependence on energy from fossil fuels, therefore promoting at the same time the environmental and economic sustainability (EC, 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; Oldfield et al, 2016).

New sources of economic value for actors involved in the supply chain as well as social benefits for the society (Boehlje & Bröring, 2011; Marotta & Nazzaro, 2012) can be unlocked by using waste materials for producing valuable novel products (Laufenberg et al, 2003). Potentially, a virtous example for generating new market and non-market values could be find in the valorization of the citrus waste (known in Italy as "pastazzo").

The pastazzo management represents currently a huge economic problem for citrus industries due to the high costs for pre-treatments before its disposal (Ledesma-Escobar & de Castro, 2014; Sharma et al., 2017) as well as a potential unexploited resource for the society. To explain this in more detail, some more practical information is needed. Citrus fruits, more narrowly oranges, lemons, limes, grapefruits and tangerines cultivations are among the most cultivated fruits all over the world (Lin et al, 2013; Sharma et al., 2017). The volume of citrus processed every year in the world is about 31.2 million tonnes (BP, 2012) whereof roughly 50-60% of the total weight of fruits is waste, pastazzo (Interlandi & Bertin, 2014; Wikandari et al., 2015; Sharma et al., 2017). Pastazzo is mainly composed by water (75–85%), mono and disaccharides (6–8%) and by a limited presence of oils in peel waste. However, essential oils represent a dangerous source of environmental issues (Taghizadeh-Alisaraei et al., 2016; Sharma et al., 2017).

To date, several biotechnological strategies have been developed in order to valorise pastazzo, therefore converting potential environmental and economic problems (Wikandari et al., 2015) into a valuable resource. Some of these strategies consist into: pectine's extraction (Tamburino & Zema, 2009; Pourbafrani et al., 2010; Interlandi & Bertin, 2014), dietary fiber extraction (Fernández-López et al. 2004; de Moraes Crizel et al., 2013) biogas production (Interlandi & Bertin, 2014; Calabrò et al., 2016), ruminant feeding (Bampidis & Robinson, 2006) and essential oil (particularly D-limonene) extraction (Lin et al., 2013). As this regards, Vergamini and co-authors have demonstrated, using a simulation model, the possible profitability of producing innovative products obtained by processing citrus by-products in the Mediterranean area (Vergamini et al, 2015).

However, in order to move technology from lab to market, it is necessary that government supports strategies and mechanisms to bridge research and industry, fostering collavorative R&D schemes between the involved actors (Mohan, 2016): Moreover important financial investments are required for the involved actors for fostering industrial adoption of the above cited possible innovations (Vergamini et al., 2015) which cannot be performed without first understanding and then removing the possible barriers for the adoption and the diffusion of technological innovations (Vergamini et al., 2015; Long et al., 2016). Adoption of disruptive innovations often needs a structural reorganization of the supply chain. Thus, one barrier of adoption of the technology, has been documented by the literature to be represented by the lack of cooperation/coordination among the involved actors within the new supply-chain (McCormik & Kaberger, 2007; Cembalo et al., 2014) Indeed, contracts mechanism can be considered as an effective way to achieve supply chain cooperation and integration, since it delivers flexibility, therefore promoting large participation (Abebe et al., 2013; Handayati, 2015). A preliminary investigation about some relevant contract attributes is crucial to develop cooperation among stakeholders and to share the risk of investment among all actors involved in a new and eco-innovative supply-chain (Cembalo et al, 2014) decreasing the risk and uncertainty about the innovation adoption (Wamisho Hossiso et al., 2017).

Sicily is the Italian region leader for the citrus cultivation (ISTAT, 2016)1. Processing citrus by-product in Sicily, via a multifunctional plant, could represent the solution of two main issues: i) low returns of citrus cultivation and consequently its abandonment and ii) the environmental problem associated to the pastazzo management (Cerruto et al., 2016). Nevertheless, an innovative multifunctional plant is costly and risky since the adoption of technological innovations is strongly required.

The first aim of the present study is focused on analysing the current (status- quo) waste management of pastazzo in Sicily region. More in detail, by means of the statistical analysis of data

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

acquired in the Sicilian citrus plants on 2015, determinants and barriers that influence entrepreneur's choice to dispose pastazzo are investigated. Secondly, we analyzed contract attributes preferred by citrus transformers in order to promote vertical coordination, identifying, at the same time, potential barriers for the implementation of a multifunctional plant to transform pastazzo for its full valorization into valuable by-products.

2.2. Background

2.1.1 Possible uses of citrus by-product

Citrus by-product is composed by water (about 75–85%), mono and disaccharides (glucose, fructose, sucrose; about 6–8%), polysaccharides (pectin, cellulose and hemicellulose; about 1.5–3%), and it is characterized by a significant presence of essential oil (EO) composed in particular by D-limonene (about 83–97%) (Bicas et al., 2008). Some factors influence the composition of citrus fruit, for example growing conditions, variety and climatic situations (Kale & Adsule, 1995). In addition, it includes 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 and Henry, 1991).
Recently, citrus peel residues have attracted more attention. Several European and non-European studies have highlighted the importance of citrus wastes valorisation both for enhancing industries' competitiveness (also by suppressing the disposal costs), and for struggling a growing environmental problem (Tripodo et al., 2004; Ruiz & Flotats, 2014; Vergamini et al., 2015; Sharma et al., 2017). Oils contained in citrus peel waste inhibit bacterial and yeasts activities, decreasing the decomposition action (Sharma et al., 2017). Hence, the direct disposal of citrus waste (without previous oils extraction) generates environmental problems. To treat pastazzo before its disposal is necessary to discourage environmental problems and, at the same time, to valorise citrus waste. Several technological methods are developed during the last years.
One of the most important and profitability strategy developed to transform pastazzo is the extraction of pectin. Pectin is a polysaccharide commonly contents in fruits and it is largely used by European food industries, in particular for jams preparation (Interlandi & Bertin, 2014). Recently, an integrated method was adopted in order to increase pectin yield by citrus peel. By using this method, about 39 Kg of pectin can be produced per wet citrus waste ton (Pourbafrani et al., 2010). Many components of citrus by-product could be used to create functional foods, especially dietary fiber (Marın et al., 2002), made up of polysaccharides and lignin that are not absorbed in the human

intestine (Asp, 1987). Dietary fiber from citrus by-products has a lot of cellulose and minor concentration of lignines, pectins and hemicellulose (Fernández-López et al. 2004), thus, they have a higher portion of soluble dietary fibers than those coming from wheat bran (Gorinstein et al., 2001). Moreover, fibers from citrus waste are well-stocked of bioactive compounds such as flavonoids and C-vitamin, with antioxidant power (Fernández-López et al. 2004). Since fibers from citrus by-product contain some different functional nutrients, it has been suggested to include these components in frequently consumed foods in order to avoid the fiber deficit in actual human diet (Fernández-López et al. 2004). More recently, literature suggests that orange fiber could be considered a good alternative as a fat replacer in ice cream since its functional properties reduce about 70% of ice cream's fat (de Moraes Crizel et al., 2013). The growing interest in bioenergy has suggested citrus waste utilisation for biogas production. Indeed, dried citrus by-product is used for domestic heat since its efficiency is slightly lower than those produced by other kind of biomass (Giametta et al., 2004).

The biogas yield is about 87,6 Nm3 for each ton of citrus by-product (Interlandi e Bertin, 2014) and it depends on different factors such as citrus variety, temperature, pH and microbiological characteristics of biomass (Tamburino & Zema, 2009). Recently, the Iran country, the second largest oil reserves in the Middle East, is developing the possible use of citrus waste as source of biofuels (Taghizadeh-Alisaraei et al., 2016).

A large development has gained the use of citrus by-product in ruminant nutrition (Grasser et al, 1995). It is a very important aspect since it reduces the competition for grains between livestock and humans (Bampidis & Robinson, 2006). The possibility to introduce citrus by-product for ruminant nutrition is due both for the availability of soluble fibers and for the ability of ruminants to ferment large quantity of fibers (Grasser et al., 1995). Citrus pulp can be given to ruminants as fresh product or as silage, even if citrus pulp is usually fed dehydrated (Bampidis & Robinson, 2006).

Citrus molasses and citrus sludge are also used for livestock diet. The first one it could be a source of feed energy for cattle (Wing et al., 1988) while, the second one, could be considered feedstuff since it has abundant amino acid components (Coleman and Shaw, 1977).

Other valorisation strategy for citrus by-product concerns the use of D-limonene by chemical industry. It is an essential oil that can be used to build chemical structures such as renewable bisolvent that can be considered like environmentally alternative to the halocarbon solvent (Kerton, 2009). D-limonene is also a fragrance compound for the production of adhesive terpene resins (Braddock,1999). As stressed above, citrus residues are bio-waste feedstock which may be valorised in several different chemicals and biofuels ways (Demirbas et al., 2011). Two years ago, an innovative Italian start-up has obtained textile fiber from pastazzo in order to create a functional dresses since they hydrate skin by releasing vitamins [2]. Nowadays, a pilot Spanish company has developed a cascade-type valorisation approach in order to convert citrus by-products into cattle feed pellets, essential oils, biofuels and finally, it is possible to purify water used for the process applying a pervaporation/condensation approach (Lin et al., 2013). The high-sorption capacity of citrus by-product has also gained more attention for wastewater remediation from heavy metals contamination (Kausar et al., 2013).

Even if potential benefits of citrus by-products are highlighted in literature studies and more effective and efficacy techniques are recently developed (Sharma et al, 2017), to implement a bioeconomy strategy is necessary to consider some important factors such as governance, economic availability, personal and societal attitudes (Golembiewski et al., 2015; Van Lancker, 2016).

2.1.2The Sicilian citrus by-product supply chain

Sicily is the Italian region leader for the citrus cultivation, with about 60% of national citrus cultivated areas (ISTAT, 2016)[3]. The greater concentration of cultivations is along the regional coasts and about 40% of total orange trees are in Catania, Siracusa, Enna and Agrigento.

The overall quantity of citrus processed in Sicily region is about 40% of the regional yield that corresponds to the 20% of the national one (Cerruto et al, 2016).

The Sicilian citrus industries may be distinguished in small firms, generally family plant with one or two employees (that generally use old process system) and medium-big companies with more than 20 employees (Cerruto et al., 2016). Usually, citrus transformation is organised into two steps: the first one consists in a basic transformation to obtain citrus concentrates, made by small firms, while, successively, larger plants complete the transformation and sell processed citrus products on market (Aguglia et al., 2008). As stated above, after technological process, a large quantity of fresh citrus (about 65%) is waste.

Citrus processed waste is considered a serious issue if there is not a regulatory framework. High costs for disposing citrus wastes induce opportunistic illegal behaviours by the citrus processing industries. Indeed, in 2012, Sicilian's reporters have highlighted the local environmental problem due to the illegal management of citrus by-products. A policy inquiry named "Last Orange Operation" reports an illegal disposal of "pastazzo" in different Sicilian areas since citrus wastes are

[2]http://www.orangefiber.it/

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

throw in streams and in private or public plots (without pre-treatment), causing several environmental problems4.

Opportunistic and illegitimate behaviours have been triggered also by the lack of specific regional legislation until 2012 when the Sicilian Regional Department of Agriculture and Food Resources, by the document "Use of by-products of Sicilian citrus industry", classifies "pastazzo" as citrus by-product rather than waste.

In Sicily region, also the cultivated areas reduction and the abandonment of citrus production are happening (Vaccaro, 2011).

Indeed, it is important to highlight that from 1992 to 2014, in Sicily region about 33.000 hectares with citrus were lost (Cerruto et al., 2016), since farmers have shown economic difficulties by receiving an insufficient income to continue the cultivation.

In this context, to improve citrus by-product valorisation, is required. In particular, by creating a multifunctional plant to process pastazzo, may be possible to create economic value for the firm and social benefits for citizen.

Indeed, the "pastazzo" valorisation reduces companies' costs for waste disposal creating economic value for involved actors and indirectly, decreases the risk of environmental problems.

However, the multifunctional plant adoption is not so easy due to the barriers about innovation adoption; one of them, is the high risk perception (Long et al., 2016). Hence, to share the risk of investment among stakeholders, the integration and coordination in the supply chain are necessary (Handfield & Nichols 2002). To manage integration and cooperative action, flexible contracts could be established in order to increase the probability that a large number of actors take part in the supply chain (Abebe et al., 2013; Handayati et al., 2015).

Contract design have been mainly explored in bio-energetic supply chains (Cembalo et al., 2014) in witch different conditions have been take into account such as minimum price or price guaranteed, the contract's length and the renegotiation option, the possibility to share know how and technology and finally, the definition of a minimum volume of product by farmers (Cembalo et al., 2014).

To "make a picture" about the actual destination of pastazzo in Sicily region, pointing out determinants and barriers of choice destination, is convenient to improve and to increase the citrus by-product valorisation. Subsequently, to investigate the propensity of citrus transformers to take part in a supply chain to valorise pastazzo and to evidence contract attributes that they prefer, is basic to create an effective citrus by-product supply chain in Sicily.

[4] http://www.tempostretto.it/tags/operazione-last-orange; http://www.24live.it/69631-operazione-last-orange-traffico-illecito-di-rifiuti-sigilli-alla-canditfrucht-ai-domiciliari-nunzio-calabro

2.3 Data and method

2.3.1 Data collection and description

The aim of the present work is two-fold: i) firstly, it analyses determinants and barriers affecting entrepreneur's choice on pastazzo's destination (biogas, pectin or feedstuff); ii) secondly, it investigates citrus transformers' propensity to participate in the realisation of multifunctional plant in order to promote citrus by-product. More precisely, we investigate how contract's features may influence the willingness of entrepreneurs to participate in the pilot plant realisation to produce biogas, dietary or textile fiber, pectin, animal feed or soil fertilizing by processing pastazzo.

The sample of this work is composed by only 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 surveyed firms.

Sample information were about: a) socio-demographics' aspects about entrepreneur and company's structural characteristics; b) current waste management adopted; and c) a choice-based contingent valuation about potential contract's typologies between companies' citrus transformation and other private (or public) company.

Table 2.1. Sample characteristics

PLANT	PROVINCE	AGE	GENDER	N-YEARS	PRODUCT'S TYPOLOGY	ORANGE (t)	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	Compost
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**	

On the basis of the available data, about half of plants are located in Messina (54%), frequently conduct by male (81%) the age on average is 54 years old (42 the youngest entrepreneur and 74 the oldest entrepreneur). The average run-years of companies are 22 and the youngest is 8 years old, while the oldest is 47 years old. As for the process transformation, the 54% of the companies transform oranges and lemons, whereas the left 46% transform also other citrus fruits. The remainder of the work focuses specifically on orange by-product. In 2015 each sample's firms has 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, orange by-product is used to produce biogas (45%) with a little difference (36%) converted into pectin, and two sample's plants transform pastazzo to produce: animal feed (first case), and soil fertilizer (second case). If orange by-product is not processed *in situ*, *pastazzo* has to be dispatched on average about 82 km far from the processing firm.

2.3.2 Empirical framework and Methods

Two different choice models were implanted in this study (McFadden ,2001).

The first choice model analyses entrepreneur's preferences about actual pastazzo's destination (analysis of the status-quo). In what follows, left hand side represents the probability Pr that the *i*th entrepreneur faced with *J*-alternatives (such as biogas, pectin and feedstuff) will take the choice *Y*i. According to the conditional logit model, such a probability is given by

$$\Pr(Y_i = j) = \frac{e^{\beta' z_{ij}}}{\sum_j \ e^{\beta' z_{ij}}} \qquad [2.1]$$

where *zij* indicates entrepreneur *i*'s individual characteristics as well as choice-specific attributes, whereas *β*' (reciprocal of z_{ij}) is a model-parameter.

As for the second aim of the present study, a the choice experiment approach was used to examine stated preferences of citrus transformers for different contract attributes in order to promote vertical coordination, identifying at the same time the trade-off between attributes and the marginal WTP for each attribute. Previous studies have used choice experiment to analyse contract's attributes (Roe at al., 2004; Cembalo et al., 2014).

Two different alternatives of contract have been shown to the entrepreneurs. Contract alternatives were characterized by a different composition of attributes and levels. The differences between contract's typology are based on:

1) The length of investment (between 15 and 20 years);
2) The risk and the remuneration of investment (annual rate from 9% to 20%);
3) The presence of equity guarantees;
4) The possibility to take part on plant management.

Valuating different alternatives and their characteristics, interviewed can chose one of the two alternatives or no alternatives. Each entrepreneur has valuated four different (each one composed by two alternatives) alternatives, generating 44 (11*4) choice experiment results.

Table 2.2. Attributes and levels of contracts

Attributes	**Level definition**	**Mean**	**Std. dev**	**min**	**Max**
Risk and remuneration of investment	Random extraction by uniform distribution, from 9% to 20%	14.77	3.84	9	20
Equity guarantee	Presence (1) or absence	0.50	N.A	0	1
Length of investment	Random extraction by uniform distribution, from 15 to 20	17.54	1.69	15	20
Management power	Presence (1) or absence (0)	0.50	N.A	0	1

N.A: not applicable

According to this model, considering the different contract's alternatives (j) shown to the i-th entrepreneur, the utility associate to each alternative preferred by the entrepreneur is a linear function composed by all attributes that identify the contract:

$$U^i_j = f(\mathbf{x}_j) + \varepsilon^i_j \qquad [2.2]$$

where $\mathbf{x}_j$ is an attributes' contract vector. According to the random utility theory, the utility U^i_j is composed by the observable component $\boldsymbol{B}\mathbf{x}_j$, where $\boldsymbol{B}$ is a vector of parameters and ε_j is an error component:

$$U^i_j = \boldsymbol{B}\mathbf{x}_j, + \varepsilon^i_j \qquad [2.3]$$

B parameters could be assessed applying a logit model and maximum likelihood estimation (Amemiya, 1985).

2.4 Results

The first aim of the present study wants to analyse determinants and barriers about actual entrepreneur's choice on pastazzo's destination (biogas, pectin or feedstuff).

Table 2.3. *Conditional logit results*

Variable	Coef.	std.err	t-stat	p-value
ln (distance)	-1.09	0.39	-2.78	0.005
Biogas × age	0.13	0.03	4.5	0
Pectin × *ln* (return past)	-14.37	3.94	-3.65	0
Feedstuff × *ln* (return past)	-5.80	2.60	-2.23	0.026
Pectin × small	-3.74	2.82	-1.33	0.185

Wald chi2(5) = 44.17; Prob > chi2 = 0.0000 ; R2 = 0.5096;

Results about conditional logit show that some aspects influence significantly the entrepreneur's choice. In particular, the probability to valorise pastazzo is negatively influenced by the distance between companies and plants for transforming orange by-product. Furthermore, the return of pastazzo influences negatively the orange by-product transformation into pectin and feedstuff. However, the probability to transform orange pastazzo into biogas is positively influenced by the age of the entrepreneur. More specifically, the older entrepreneur tends to choose the production of biogas by using orange "pastazzo" than the younger one. The small dimension of plant seems not influence pectin destination. Following figures also evidence that distance represents a barrier for the orange by-product valorisation (fig 2.1) and the return of pastazzo has negative influenced on pectin and feedstuff production too (fig 2.2 and fig 2.3)

Figure 2.1. *The relation between the distance (Km) and the probability to valorise pastazzo.*

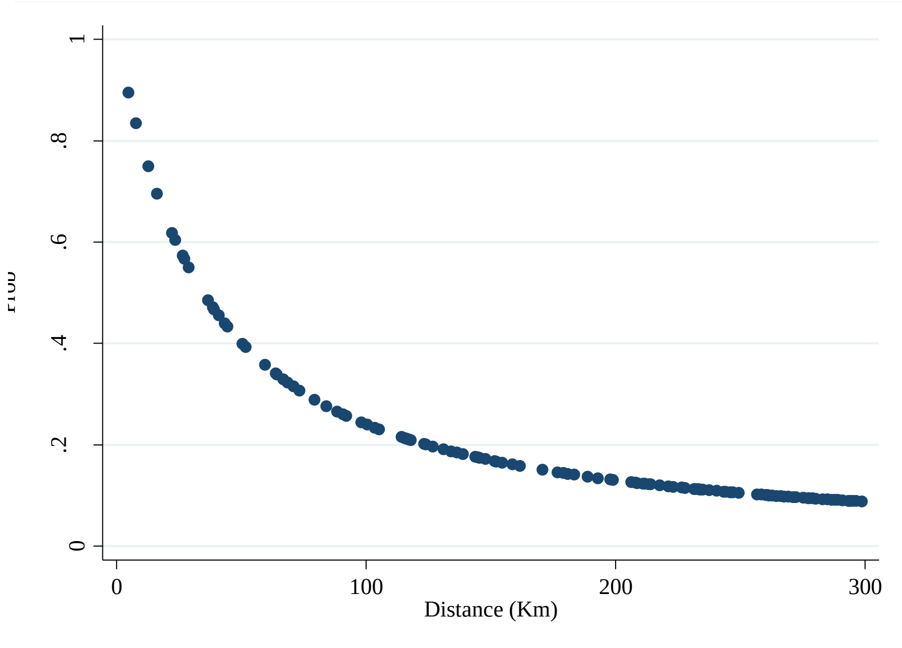


Figure 2.2. *The relation between orange by-product's return and pectin's production.*

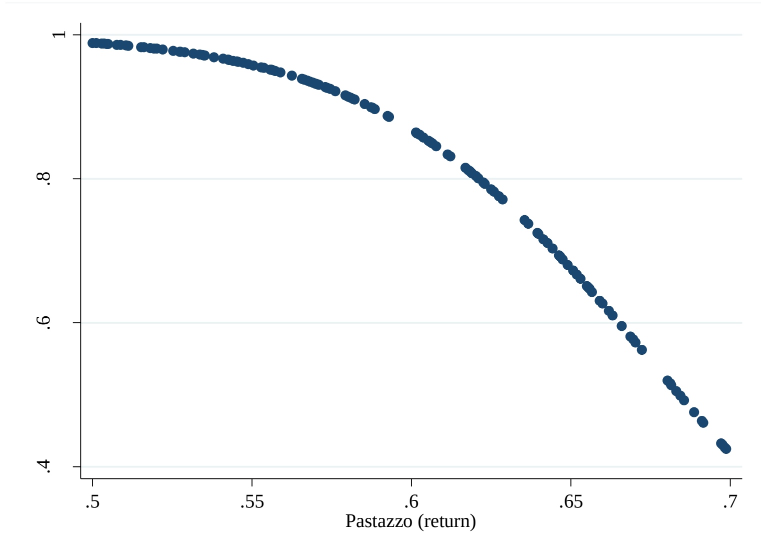
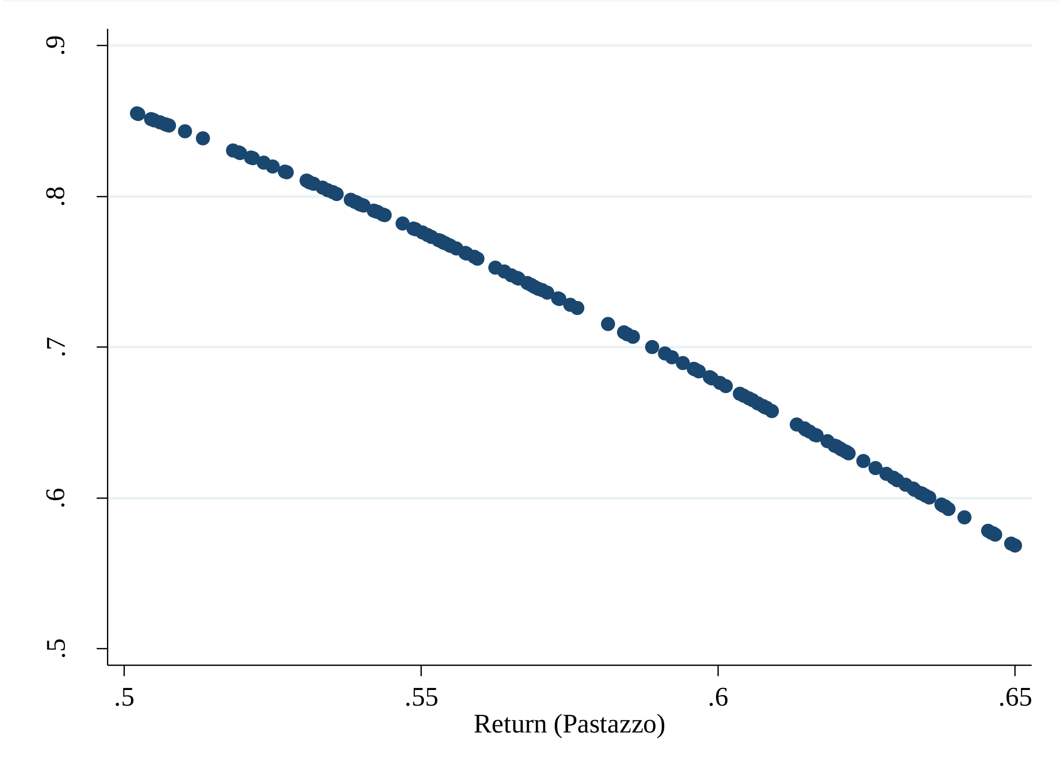


Figure 2.3. *The relation between orange by-product's return and feedstuff's production.*



The following table, in line with the second aim of the present study, evidences entrepreneurs preferences about contract attributes in order to build a pilot plant, in Sicily region, for orange by-product transformation.

Table 2.4. Conditional logit (fixed effect)

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
Equity guarantee	4.037	1.877	2.150	0.031	56.681
Length of investment	-0.207	0.114	-1.820	0.069	0.813
Management power	1.209	0.772	1.570	0.117	3.349

Model results show that the only contract attribute that is not significant for entrepreneur is the “management power”. In other words, the possibility to take part in the management of plant by-product valorisation is not important for interviewed. The estimated coefficient is, in fact, not significantly different from 0 (1.209, p-value 0.117). Important factors statistically significant are the other attributes considered in this analysis. This means that entrepreneurs prefer a short investment characterised by low risk and low remuneration. Furthermore, stakeholders prefer the guarantee on money. This last contract attribute seems to have major influence on entrepreneur’s choices than the others. Indeed, figure 2.4 displays the relation between the risk and the remuneration of the investment and the probability to take part in the investment to valorise orange by-product.

Figure 2.4. *The influence of risk and remuneration of investment and the presence of the guarantee on money on the entrepreneur's probability to invest.*

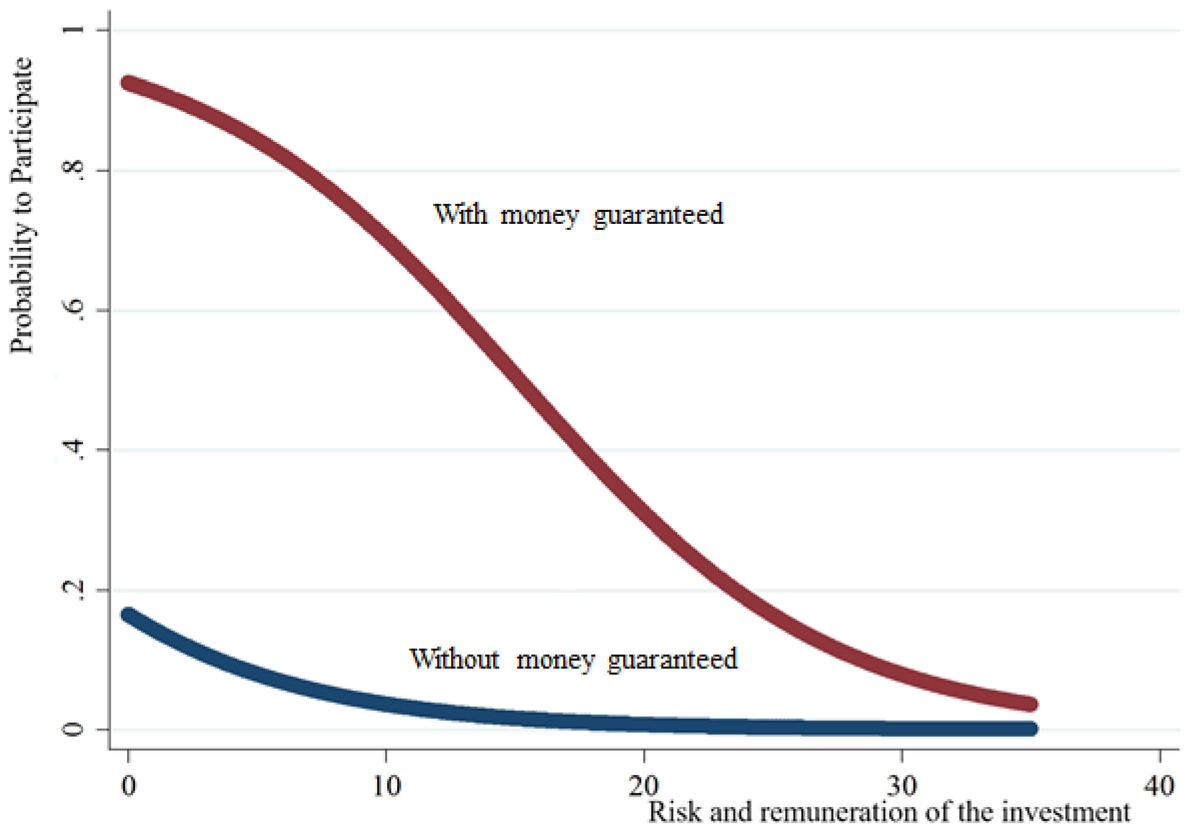


Figure 2.4 evidences that the entrepreneurs' willingness to participate to the investment is negatively influenced by the risk and the remuneration of the investment. However, the possibility to guarantee investment increases significantly the entrepreneur probability to take part to the investment.

2.5. Discussion and Concluding remarks

The implementation of specific technological tools to valorise pastazzo, may be viewed as an effective bio-economy strategy to decrease both economic and environmental problems (Wikandari et al., 2015; Taghizadeh-Alisaraei et al., 2016). Even if the technological feasibility to process pastazzo is increasing in all over the world, researches about technologies adoption and implementation in bio-economy supply chains, are relatively scarce.

In 2014, Cembalo and co-authors have analysed governance mechanisms in a bio-energy supply chain. By investigating contract attributes, potentially determinants and barriers about the implementation of a bio-economy strategy have been pointed out (Cembalo et al, 2014). One year later, the economic sustainability of citrus by-product in the Mediterranean area was investigated (Vergamini et al., 2015). This study has evidenced the economic profitability of some bio-technological strategies to valorise pastazzo, by confirming the possibility to create economic value in a citrus supply chain by processing pastazzo. However, the analysis about the implementation and the governance mechanisms to manage citrus by-product supply chain, as well as the probability to take part in a supply chain to valorise pastazzo are still rare.

The present study has investigated possible factors for the Sicilian's citrus by-product valorisation. In particular, it has analysed (first aim) determinants and barriers affecting entrepreneur's choice on actual pastazzo's destination (biogas, pectin or feedstuff). Then, as for the second aim, citrus transformers' preferences about contract characteristics to take part into the realisation of plant to valorise pastazzo, have been investigated.

The study relies on data collected in 2015 dealing with 11 orange transformation companies, solely, and located in three different Sicilian provinces: Messina, Catania and Palermo. The aims were tackled by the conditional logit model, whereas the citrus transformers preferences were investigated by means of a choice model. Outcomes show that the probability to valorise pastazzo is negatively influenced by the distance between companies and plants for transforming orange by-product. In a recent study, the increasing transportation costs of citrus waste are considered constraints to the pastazzo valorisation (Vergamini et al., 2015). In this case, distance is considered a proxy of transport's costs, thus, one can argue that the realization of a pilot plant quite near to the companies could enhance the entrepreneur's propensity to valorise pastazzo. The return of citrus by-product influences negatively the orange by-product transformation into pectin and feedstuff. Instead, the probability to transform orange pastazzo into biogas is positively influenced by the age of the entrepreneur. This implies that the probability to designate pastazzo to the biogas production seems to increase if the return of pastazzo is high and if the entrepreneur is not young. This is probably due to the short distance between citrus transformation plant and plant to process pastazzo in biogas.

As for the contract attributes preferred by the interviewed entrepreneurs, results suggest that the possibility to take part in the plant management is not important for citrus transformers. On the contrary, entrepreneurs prefer a short contract, with small investment and characterised by low risk and low remuneration, whereas the guarantee on money is considered the most important attribute. As for the duration of the contract, Cembalo et al. (2014) have investigated farmers' preference about the duration of contract in a new bio-energetic supply chain. As well as mentioned farmers, our interviewed (citrus transformers) also prefer a short length of contract.

As for the risk perception, our outcomes are in line with some previous studies (del Río Gonzalez, 2005; Johnson, 2010) that consider the risk perception one of the most important barrier for the innovation adoption. Indeed, the financial cost due to the high initial investment increases the risk perception and represent "the core barrier" of the pro-environmental innovation adoption (Long et al, 2016). The financial risk perception in co-innovation system is associated to the direct investment risk and to the opportunity cost of the investment (Abahari et al., 2017). The required presence of guarantee on money, the short duration of contract and the low risk and remuneration, highlight a high economic risk perception by interviewed that could obstacles the multifunctional plant realisation.

Even if the present study is characterised by some limitations, for example the low representatively of the sample since it considers only medium and largest plants, results are in line with previous studies and give preliminary information for planning a multifunctional plant in Sicily region. To understand factors that could influence actors' participation in the implementation of multifunctional plant, is critical to improve the co-innovation, meant as the common vision and common goals shared by actors involved in a supply chain (Abhari et al, 2017).

The distance to have to travel to dispose pastazzo could negatively influences the propensity of actors to participate in the new plant realisation. As consequence, it is important to minimise the distance between citrus process companies and the processing plant. Moreover, to evidence contract attributes preferred by actors may be useful to make a contract shared by several participants.

Future research could investigate attitudes to collective action and cooperation both for citrus transformers and for farmers. This could be important in order to investigate other potential determinants and barriers to the creation of a supply chain that includes the citrus by-products valorisation. Moreover, entrepreneurs and farmers' propensity to adopt organisational or a product innovation is a fundamental aspect to make new supply chain, since such results could be useful to policy makers to increase and improve networking among all the involved actors.

3 GOVERNANCE MECHANISMS TO MANAGE OLIVE CAKE SUPPLY CHAIN

3.1 Introduction

The European Commission has recently emphasized the importance of following sustainable and innovative strategies to assure, at the same time, food security and protection of natural resources (EC, 2012). Bio-economy-based food production could give useful basis to achieve, simultaneously, these aims. In other words, the bio-economy assumes the production of renewable biological resources and their conversion (including by-products) into value added products such as food, feed, bio-based products and bioenergy (European Commission, 2012).

The use of biomass, provided that at each stage it gains the highest possible value (de Besi and McCormick, 2015), leads to the solutions of many problems of the fossil-input-based economy, energy diversity, and climate change mitigation (Vandermeulen et al, 2012; Smeets et al, 2013).

Thus, agricultural biomass, such as wastes and by-products, have gained an increasing attention (Mirabella et al., 2014; Oldfield et al., 2016; Wamisho Hossiso et al., 2017) since the valorization of organic wastes, by decreasing the amount of wastes to dump is also in line with EU directives (99/31/EC 2015). The development of by-products supply chain may have two main impacts: i) increasing economic benefits for the involved actors and ii) reducing the amount of agricultural wastes and their environmental impact (Handayati et al., 2015).

Among the different sources of organic and agricultural waste, the solid residue of olive oil industry represents one of the most valuable resource for its possible uses. More in detail, a large amounts of wastes are generated by the olive oil extraction industries (Dermeche et al., 2013). The olive oil industry produces, after the oil extraction, two types of by-products: a solid residue (known as fresh olive cake) and a liquid fraction known as olive mill waste-water (OMWW) (Dermeche et al., 2013).

The fresh olive cake is more (three phase system production) or less (two phase system production) damp (Di Giovacchino et al., 2006). Furthermore, olive cake is one of the main by-product of olive oil production (Brlek et al, 2013), and it is a semi solid mixture composed by oil residues, pulp and fragments of the pits. It is mainly composed by sugars (polysaccharides), proteins, fatty acids, polyphenols and polyalcohols (Karantonis et al., 2008; Mirabella et al, 2014).

However, phenols encompassed in both mentioned by-products (olive cake and OMWW) decrease the microbiological activity in the soil (Dermeche et al., 2013), causing negative effects on soil fertility.

Several literature studies have highlight the possible use of olive oil by-products, such as olive cake, as healthy and functional products (Ghanbari et al., 2012; Uribe et al., 2013) and/or to produce active carbon (Stavropoulos and Zabaniotou, 2005). Olive cake is also used: i) for animal feed (Suarez et al., 2009; Mirabella et al., 2014), ii) as fertilizer in agriculture (Mirabella et al 2014), or iii) to produce biogas (Ghimire et al., 2015). Finally, the by-products in olive oil production could be used also as biofuel (Vega-Galvez et al., 2010; Brlek et al., 2013).

However, previous literature has evidenced several barriers to the adoption of technological innovations in the supply chain (Long et al., 2016) and furthermore, in the agri-food sector the investments in technologies are often lacking (Vergamini et al., 2015). The coordination and the quality of interactions among actors could be considered a key elements for enhancing value co-creation by adopting technological innovations and for overall supply chain performance (Pedrosa, 2009; de Besi and McCormick, 2015), since stakeholders work together for a defined and commonly aim (Simatupang and Sridharan, 2002; Sirias and Mehra, 2005). The concept of coordination in a supply chain is strictly linked with the concept of interdependence among activities of actors (Handayati et al., 2015), such as supplying agricultural inputs, transporting and processing, that involve a lot of people (Aramyan et al., 2006), so effective coordination mechanisms are required.

Literature evidences several coordination mechanisms to manage interdependencies aiming to improve supply chain performance. Handayati et al. (2015) identify four different coordination mechanisms: i) supply chain contract, ii) information sharing, iii) joint decision-making and iv) collective learning. The contract mechanism, that manages involved actors on the basis of quantity, time, price and quality (Kanda and Deshmukh 2008), is the most diffuses coordination mechanism in the agri-food supply chain, and it is generally adopted to manage tactical and operational decisions (Tan and,Comden 2012). However, it is important also implement contract mechanism as a strategic tool to involve supply chain participants in long-term relationship (Folkerts and Koehorst, 1997). In agreement with this last concept, some recent studies have investigated contract mechanism as a tool to enhance vertical coordination in the biomass supply chains (Wamisho Hossiso et al 2017; Xi et al., 2016; Cembalo et al., 2014; Okwo and Thomas, 2014; Li and Ross, 2014). Wamisho Hossiso et al. (2017) has analysed the price and the quantity-based contract design on willingness of farmers to grow biomass for ethanol production. The willingness of local farmers to convert wheat cultivations into bio-energy crops in a rural marginal area of South of Italy was also investigated (Cembalo et al., 2014).

In the Mediterranean area, the olive oil production has a large economic relevance, in terms of production and consumption (Salomone and Ioppolo, 2012).

Italy is the second European producer of olive cake. In particular , Sicily is one of the main Italian region in the olive oil production. In 2016, this region has produced over one million of tons of olives to produce olive oil (ISTAT., 2016). Thus, take into account that the 26% of fresh fruit is dried olive cake (Al-Hamamre et al., 2014), the quantity of olive cake in this region, is high too.

However, the large quantity of by-products obtained after olive oil extraction could represent an environmental issue (Niaounakis, and Halvadakis., 2006) since, wastes produced during a short period (October-February), without long enough temporal lags for disposal (Erdem Ismal, 2013; Ghimire et al., 2015), could increase illegal disposal.

Furthermore, the high cost to dispose olive cake is generally payed by farmers, hence the cost to process olives is increasing. During the last years a decrease of profitability was observed in Italy especially in the smallest farms. The loss of profitability of olive oil production has generated the olive cultivation abandonment, especially in Sicilian marginal areas (Di Vita et al., 2015). The olive cultivation desertion may result in a serious issue due to the reduction of oil production which (indirectly) affects the loss of the multifunctional role of the olive trees cultivation. In particular, this happening may play down both the important environmental services and the level of employment in the rural communities (Lanfranchi et al., 2016). Hence, to process olive cake could create economic value in the olive oil supply chain (also by reducing the disposal cost) and, at the same time, could give an environmentally friendly way to use olive oil by-products (Brlek et al., 2013; Milanese et al., 2014).

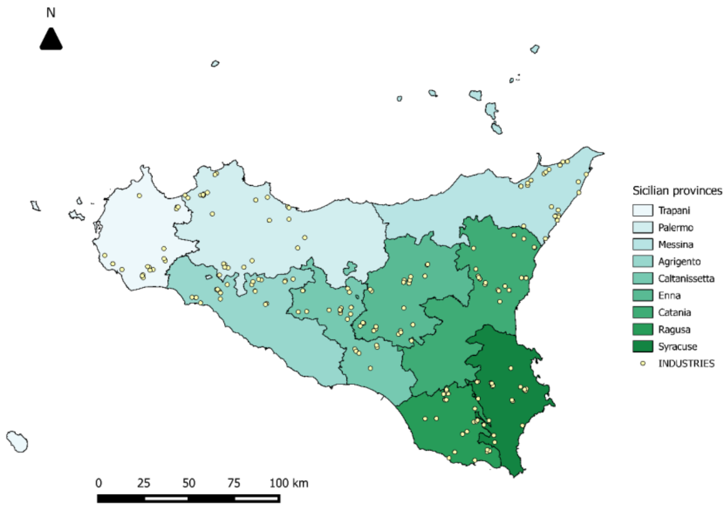
However, as stated above, even if the technical feasibility for transforming olive cake in different products (creating value) is largely developed, there is no researches about the propensity to adopt technological innovation to valorise olive cake. Moreover, studies about determinants and barriers to enhance vertical coordination in the olive cake supply chain in the Sicily region, are absent.

This paper aims to fill this gap of the literature, investigating the propensity of Sicilian olive oil producers (millers) to take part in an olive cake supply chain. The aim of this work is two-fold. First, we investigate olive oil producers (millers) propensity to join to a by-product supply chain to produce animal feed by processing olive cake. Secondly, we analyse millers stated preferences about specific contract attributes. A conditional logit model (CLM) will be used to analyse millers' contract preferences (organised in a choice experiment) regarding the olive cake valorisation.

3.2 Data description

To follow the mentioned aims, information about a representative sample of Sicilian millers, was collected. The survey questionnaire, designed by using an iterative process, gives information in order to implement a choice experiment (Hensher et al, 2005; Cembalo et al., 2014) and other statistical model to accomplish the research objectives. The sample is composed by 201 Sicilian olive oil producers (millers). Data were obtained by submitting a questionnaire with vis-à-vis interviews to millers located in all provinces of Sicily. On average, 22 millers for each Sicilian provinces (overall 9 provinces) were interviewed.

Figure 3.1. *The localisation of olive oil Sicilian industries (mills).*



The questionnaire was submitted in 2015 to capture the "stated" propensity of millers to participate in a supply chain in order to process olive cake in animal feed. The preferences for specific contract attributes to sign with the feed animal company, was also investigated. The overall sample sections were about: a) socio-demographics' aspects about entrepreneur and company's structural characteristics; b) by-products information; c) the entrepreneur's propensity to create a supply chain in order to transform olive cake into animal feed and d) different contract's typologies between companies' olives transformation and companies for processing olive cake. More articulately, the survey is composed by four sections. In the first section socio-demographic, structure and organisation information of mills were collected.

Table 3.1. Summary statistics

Olive oil producers (millers)	Mean	Std. Dev.	Min	Max
Gender (1 if male; 0 female)	1	0.427	0	1

Age (years)	52	12.852	22	88
Years of activity	17.3	10.941	1	60
Olives quantity (tons)	600.45	480.02	30	3000
Oil quantity (tons)	97.52	80.65	5.1	540
Olive cake (tons)	273.55	213.81	13.5	1350
Disposal distance (Km)	87.33	75.450	0	300

The olive oil producers interviewee are frequently men, on average 52 years old and they conduct their mill from minimum one year to maximum 60 years (on average 17 years). The observed mills have processed on average 600 tons of olives during the 2015, from 30 tons to 3000 tons (the maximum quantity of olives transformed). As for the olive oil production, the data set shows 97 tons on average (min 5 tons - the max 540 tons). In the case of the olive cake production, the minimum produced quantity is about 14 tons, whereas the maximum production is 1350 tons (with an average of about 273 tons). Most of millers stated that they have to travel on average 87 Km to dispose the produced olive cake. Sometimes, such a disposal distance may be quite large (about 300 Km) and, in other cases, it is zero (when the olive cake is disposed *in situ*).

The propensity of millers to change, as a proxy of the probability to innovate and invest, represents an important aspect since could influence the millers' propensity to participate in an eco-innovative supply chain to valorise olive cake. In the second section of the questionnaire the "propensity to change" is considered and some main features are reported in the following table.

Table 3.2 Investments and innovation in the past five years* (Absolute and relative frequency)

	Value	**Percentage**
Investments in the last 5 years:	106	53%
Land acquisition	12	6%
Machines acquisition	90	45%
New constructions	47	23%
Processing and packaging	54	27%
Marketing	29	14%
Other	0	0%
Innovations in the last 5 years:		
Cropping system changes	23	11%
Cropping techniques changes	28	14%
Organization changes	48	24%

The number of investments and innovations is greater than the number of the mills since some of them have adopted more than one.

During the last five years before the questionnaire submission, overall 53% of millers have done investments in their own firms. In particular, most of interviewee have bought machines. As for the innovation adoption, most of millers have done incremental innovation since the organizational changes prevails.

The successive section of the survey gives information to allow the second aim of the work. By implementing an experimental design approach, respondents stated their preferences, by making a choice among two contract schemes characterized by selected attributes with different levels.

A sensibly description of selected attributes was made to each miller, in order to choose (or not) the most preferred contract for each scenario. Scenarios were introduced by a carefully description of olive cake valorisation, including the importance to create value in the Sicilian olive sector. The necessity to manage the olive oil supply chain by adopting contract mechanism was also empathised. Finally, the realistic contract cards were proposed to the sample millers.

Differences about contract's attributes concern:

i) the base price, that is the unitary price payed for olive cake;

ii) the possibility to guarantee a minimum price to the olive oil producers;

iii) the definition of a minimum quantity of by-product to give to transformers, with a penalty if the minimum quantity is not reached;

iv) the length of contract (min 3 years - max 10 years);

v) the possibility to sign a new contract before the end of the previous one;

vi) the obligation for entrepreneurs to take part in meeting to share information about economic and technical aspects on supply-chain.

Three choice sets, each one with two alternatives, were presented. So, the choice experiment data has included overall (201x3) 603 millers stated preferences.

The last part of the survey is based on eleven items (defined below) to capture miller's attitude to collective action.

Table 3.3 Description of items submitted to investigate attitude to collective action

Item	**Item description**
i_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 leave.
i_2	I think that to collaborate with other millers to valorise olive cake reduces the environmental problems.
i_3	To collaborate with farms for creating a feed supply chain by valorising olive cake is a good idea.

i_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.
i_5	Farmers cooperation in the olive cake supply chain will produce profitability for me and my family too.
i_6	According to me, I can not collaborate with other farmers.
i_7	According to me, I can collaborate with other farmers.
i_8	According to me, I can eliminate misunderstanding with other farmers.
i_9	My colleagues and my friends think that influence my behaviour think that I have to collaborate in order to build an olive cake supply chain for producing animal feed.
i_10	Most of people I know and I appreciate think that I have to collaborate to build an eco-innovative supply chain.
i_11	What do you think about your risk perception?

3.3 The statistical methods

The aims of the present study are: i) to analyse the determinants of millers propensity to participate (PtP) in a supply chain to process olive cake in animal feed; ii) to investigate the millers contract preferences (CP) about selected contract attributes in order to describe contract characteristics more preferred in order to enhance the probability to take part in the olive cake supply chain. In the following part, we will describe two econometric models adopted, one for each objective. As for the first mentioned aim, that want to understand determinants that could influence the millers participation in the olive cake supply chain, the research hypothesis considers the (PtP) based on:

- socio-demographics characteristics of millers;
- mills' characteristics;
- previous experience in the supply chain contract;
- attitudes of millers to collective action .

The declared characteristics will include as casual variables in the model. The statistical model defines the probability distribution of the population, by considering the combined probability distribution of the sample.

We used the Probit model to allow the first objective of the research. The assessed parameter of each variable gives the influence of a specific variable on the miller propensity (probability) to take part in a supply chain to produce animal feed by processing olive cake:

$$\pi_i=\text{Prob}(Y_i=1)=\text{Prob}(Y_i^*>0)=\text{Prob}(-\varepsilon_i < \alpha + \boldsymbol{\delta K}_i + \boldsymbol{\beta X}_i + \gamma \mathbf{Z}_i + \boldsymbol{\tau W}_i) = \Phi(\alpha + \boldsymbol{\delta K}_i + \boldsymbol{\beta X}_i + \gamma \mathbf{Z}_i + \boldsymbol{\tau W}_i) \quad [3.1]$$

Where:

π_i: is the probability that miller participate in the olive cake supply chain;

Yi*: is the latent variable;

Yi: is the observed binary variable that show the “stated” interest (Yi = 1) or not interest (Yi = 0) of the i-th miller to participate in the supply chain: the Y_i variable is connected to the latent one as: Yi = 1 if Yi*> 0 and Yi= 0 if Yi* ≤ 0.

Ki: vector with socio-demographics characteristics of the i-th miller;

Xi: vector with structural characteristics of i-th plant (mill);

Zi: vector with previous experiences in the supply chain contract of i-th miller;

Wi: vector with variables for attitudes to collective action of i-th miller;

Φ: cumulative distribution function of normal standardised;

ε_i: error component.

The model parameters to assess will be:α, is the intercept, while δ, β, γ e τ are the model coefficients to assess.

The second statistical model we are going to speak about, was implemented to evidence millers CP to identify contract attributes preferred by interviewee. More preciously, the objective is to identify possible incentives to increase the participation in the olive cake supply chain. To design a shared contract among actors involved in a supply chain is not so easy (Markelova et al., 2009; Cembalo et al., 2014). Indeed, if millers could have different preferences about contract attributes (Abebe et al., 2013), the olive cake transformer want to sign one typology of contract accepted by all millers potentially involved in the supply chain. Thus, to investigate contract preferences is the focus of this model.

The interviewee stated preferences were analysed by adopting the choice experiment.

The choice models approach are connected to the Random Utility Theory (RUT) proposed by McFadden (2001). The objective is to analyse data take in account the probability approach. Furthermore, the econometric model implemented is the Conditional Logit (CL). The CL model allows to point out the influence of single attribute and level on the process choice.

To assess preferences about contract attributes, previous literature studies have used methods based on the random utility theory (RUT) proposed by McFadden (2001) and have implement the choice model to assess preferences on contract attributes (Roe et al, 2004; Cembalo et al., 2014; Wamisho Hossiso et al., 2017).

In this case, this model assumes that the stated preferences by miller are useful to maximise his expected utility over time. By considering a group of “C” contract alternatives shown to the h-th olive oil producer, the utility given to each contract attribute (alternative “C”) represent a linear function composed by all t attributes included in the contract:

$U^h_c = f(\mathbf{z}_c) + \varepsilon^h_c$ [3.2]

where $\mathbf{z_c}$ is the vector of contract attributes. The hypothesis is that miller chose the *c* contract alternative to maximise his "expected utility": $U^h_c \geq U^h_k$, where k alternative $\in$ C and $k \neq c$.
Thus, in order to maximize his expected utility, the miller chose the contract alternative with more preferred attributes **z**.
The probability that olive oil producer chose a specific contract *c* among all different alternatives C, is due to the probability that the *c* alternative utility is higher than other contract alternatives proposed, or it is the same:

$Pr(U^h_c) = Pr\{U^h_c > max(U^h_k,...,Uh_C)\}$ [3.3]

According to this model, the utility U^h_c is the amount of an observable component $\Omega^h z_c$, where Ω is a K parameters vector to assess, and a stochastic component ε^h_c

$U^h_c = \Omega^h z_c + \varepsilon^h_c$. [3.4]

Parameters (Ω) could be distributed in the sample by considering a distribution function defined by a position (μ) and by a scale parameter (σ):

$U^h_c = \Omega^h z_c + \varepsilon^h_c$ [3.5]

where $\mathbf{\Omega}^h = \mathbf{\Omega} + v^h$, $v^h \sim N(0, \sum_{\mathbf{\Omega}})$.
The Conditional Logit model is applied to assess parameters that represent the marginal utility of each specific contract attribute, in other words, parameters Ω or Ω^h identify the importance of attribute for miller's choice. The *choice experiment* proposed to our sample is composed by three sets of choice, each one with two alternatives of contract. The alternatives were proposed in random manner. Each alternative includes different levels of six attributes selected in a *focus group* composed by stakeholders of olive cake supply chain (Tab 3.4) and they are considered the most important in a recent studies (Cembalo et al., 2014; Wamisho Hossiso et al., 2017): 1) the base price level, 2) the minimum guarantee price, 3) the length of the contract, 4) the renegotiation option, 5) the training meetings, 6) the minimum volume guarantee of the product to manage eco-innovative supply chains. The base price was defined considering the market price (about 36 €), defined in a

uniform distribution from 32€ to 40€. The length of the investment is randomly fixed between 3 and 10 years. As for other mentioned contract attributes (minimum guarantee price, the renegotiation option, the mandatory to participate to training meetings and the minimum guarantee product quantity), they are stated by the presence or the absence in each considered contract alternative. We have identified the model parameters by using the maximum likelihood estimator (Amemiya 1985; Train 2009).

Table 3.4 Selected attributes and specific levels of the proposed contracts

ATTRIBUTES	LEVELS DEFINITION	RANGE
Base Price	Current market price plus or minus a flat amount for marketing premium or fees: value are randomly generated from a normal distribution	from 32 euros to 40 euros per tons
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 an 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	0 or 1

	to being guaranteed: values are randomly generated from a binomial distribution	

3.4 Results and discussion

3.4.1 Factor analysis

The attitude of millers to collective action was investigated by considering the TPB (Theory pf Planned Behaviour) (Ajzen, 1991). The fourth part of the questionnaire includes eleven items (table 3) to measure the TPB section whereof 5 items to investigate millers' attitudes, four items for perceived behavioural control (PBC) and two items to explore social norms. The Likert scale (7 point) was applied to score items (1= "totally disagree", 7="totally agree").
The TPB has been also used to predict farmers' intention to adopt sustainable agricultural strategies (Donati et al., 2015) and their participation in a collective action to improve environmental sustainability (van Dijk et al., 2014). The TPB theory states that a specific behaviour can be predicted by considering individual's intention (Ajzen, 1991) since behaviour is due to three factors: attitudes, social norms and the Perceived Behavioural Control (PBC). The first one (attitudes) is based on evaluations and opinions about the results of the behaviour. Social norms include what other people could think about own behaviour and finally, the PBC includes skills and/or obstacles one thinks influence the behavioural performance. Items responses were aggregate by adopting factor analysis (FA). We considers attitudinal items to be included in each latent factors if the variable has a factor loading greater than 0.4 (in absolute value), if the factor loading is lower than this value, the attitudinal variable was excluded. None eleven attitudinal variables considered were left out. Based on the FA we synthetize millers attitudinal preferences in overall three latent variables (factors). Taking into account the TPB theory, we can state that Factor-1 consists of the first five latent variables to capture miller's attitudes, in other words this factor includes olive oil producer perception about consequences of their behaviour (participation in a supply chain to valorise olive cake). The factor loading ranging from 0.78 to 0.84.

Table 3.5 Results of FA (Factor Analysis)

Variable/Item	Factor_1	Factor_2	Factor_3	Uniqueness
i_1	0.7868			0.3241
i_2	0.8064			0.3474

i_3	0.8408			0.2051
i_4	0.8493			0.2242
i_5	0.7917			0.3668
i_6		-0.6797		0.4328
i_7		0.7875		0.2682
i_8		0.7892		0.2913
i_9			0.9450	0.0920
i_10			0.9513	0.0724
i_11		0.6309		0.5050

Uniqueness is the percentage of variance for the variable that is not explained by the common factors.

Factor-2 describes the Perceived Behavioural Control, to express miller perception about his skills or barriers to participate in a collective action. By including four latent variables with factor loading from 0.63 to 0.78, the Factor-2 is defined. Finally, the Factor-3 contains two items (factor loadings 0.94 and 0.95) and describes social norms (what others people could think about me). Three factors evidenced by the FA describe the *Wi* vector in the Probit model.

3.4.2 Characteristics that influence the miller Propensity to Participate (PtP)

In the following part of the work, we will describe statistical analysis results about the first aim: to identify the miller PtP. In the table 6 independent variables used in the Probit model, are described and, successively, results obtained by using the “probit” command of STATA[5], will be evidenced. Several characteristics (the explanatory variables of the model) that could influence the propensity of millers to participate in a supply chain in order to produce animal feed by using olive cake, are evidenced in the regression results. We will discuss each significant variable of the model about socio-demographics characteristics of millers, mill characteristics, previous experience in the supply chain contract and attitudes of millers to collective action.

Table 3.6. Independent variables description.

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	N.A	0	1
X: structural characteristics of mill					

[5] StataCorp, L. P. (2013). Stata version 12.0.

Q_olives	Tons of olives processed	600,45	480,02	30	3000
Q_oil	Tons of oil produced	97,52	80,65	5,10	540
Q_o. cake	Tons of olive cake produced	273,55	212,74	13,50	1350
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					
Invest	1 if miller has invested in firm during the last 5 years, 0 otherwise	0,53	N.A	0	1
Innov	1 if miller has introduced innovations during the last 5 years, 0 otherwise	0,67	N.A	0	1
Part	1 if miller has took part in a cooperation form, 0 otherwise	0,32	N.A	0	1
Contr	1 if miller has signed a supply chain contract, 0 otherwise	0,28	N.A	0	1
W: Attitudes to the collective action					
Att	Latent variable (proxy) to measure the millers attitudes to the participation in an olive cake supply chain.	0	1	-2.39	1.55
PBC	Latent variable (proxy) to measure attitudes to cooperate with others stakeholders.	0	1	-3.45	1.74
SocNorm	Latent variable (proxy) to measure the influence of social norms on miller's choice.	0	1	-1.81	2.46

As stated above, the table below evidences the Probit model output.

Table3. 7. Results of *Probit model*: millers propensity to participate in a supply chain to valorise olive cake.

X: structural characteristics of mill	Coef.	Std.dev	*t*-stat	*p*-value	Marginal effect
Q_sansa (ln)	0,300	0,170	1,76	0,08	0,96
Loc_2	-0,859	0,347	-2,47	0,01	-0,31
Loc_5	-0,562	0,338	-1,67	0,10	-0,20
Z: Previous experiences					
Invest	-0,375	0,231	-1,62	0,10	-0,12
Part	-0,498	0,237	-2,1	0,04	-0,17
W: Attitudes to the collective action					
Att	0,717	0,114	6,31	0,00	0,23
_cons	-0,424	0,868	-0,49	0,63	

Note: Number of observations = 201; Log likelihood = -94,93; Wald $\chi^2(6)$ = 51,67; Pseudo R^2 0,21

The final probit model includes only the significant variables, so we have evidenced in the previous table the variables that are significant at least 10%. Furthermore, we have described the predictive power of the probit model (table 3.9).
The successive table evidences, for each Sicilian area, the relative and absolute frequency about the potentially millers' interest to participate in the proposed supply chain. The analysis carries out (see table 8 below) that the "stated" propensity to participate is higher than 50% in each province, giving a percentage of 71% of the total sample. Trapani is the province where all the millers interviewed (overall 20) have stated that they have a propensity for participating in a supply chain to process olive cake. High percentage (82%) of favourable millers is measured in the province of Agrigento, while, it seems that in Siracusa only 12 interviewed on 22 (the 55%) are interested in the supply chain creation.

Table 3.8. Frequency distribution of interviewee and their stated interest in the supply chain to valorise olive cake.

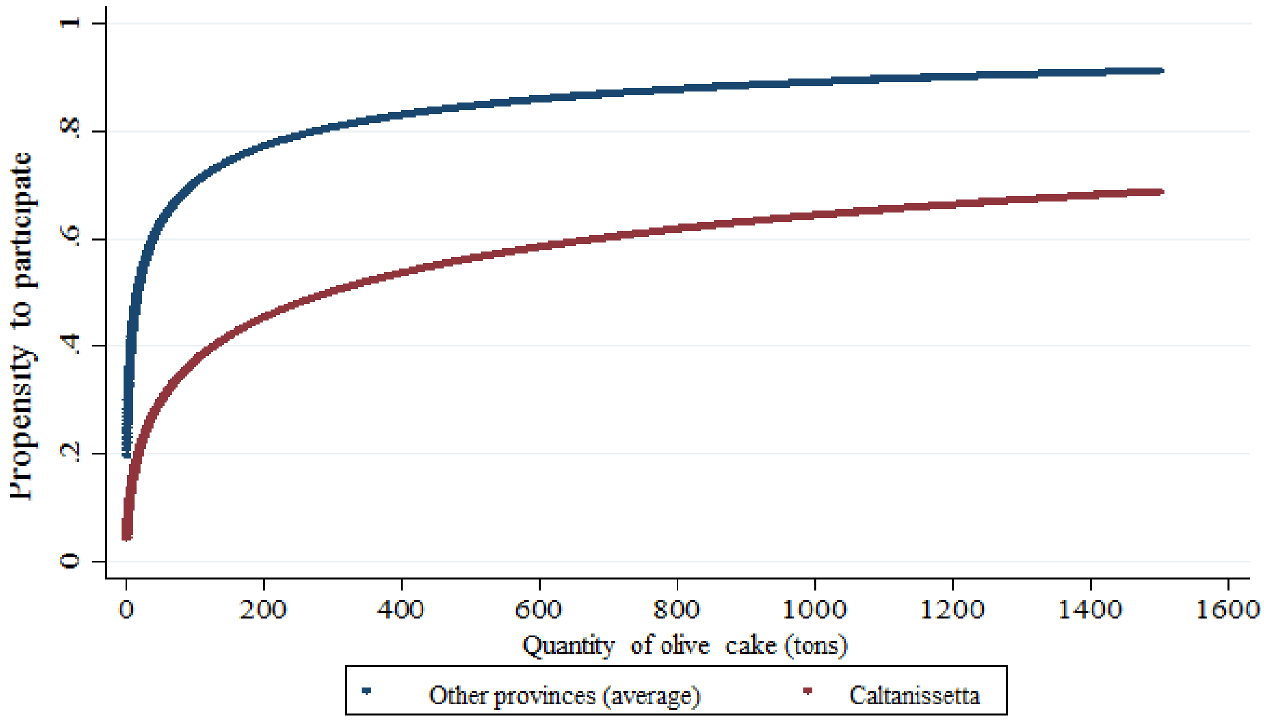
	#interviewed millers	#interviewed interested	#interviewed interested/#total interviewed
Agrigento	22	18	82
Caltanisetta	21	12	57
Catania	22	13	59
Enna	22	16	73
Messina	25	16	64
Palermo	25	19	76
Ragusa	22	17	77
Siracusa	22	12	55
Trapani	20	20	100
Total	201	143	71

Table 3.9. Predictive power of the *Probit* model

Sensitivity	92.31%
Specificity	50.00%
% Correct prediction	80.10%

Results about the Probit model, to investigate the Sicilian millers PtP in a supply chain in order to valorise olive cake, show that the **socio-demographic characteristics** of miller appear not significantly influence the olive oil producer propensity to take part in an olive cake supply chain. This means that the age and the gender of interviewed not influence the propensity of miller to participate. Furthermore, the age of activity seems to be insignificant. On the other hand, mill's characteristics (**structural characteristics**) seem to impact the PtP. Indeed, the quantity of olive cake produced by mill increases the millers' PtP. The graphs 1 evidences the relation between the willingness of miller to participate and the quantity of olive cake produced in the mill. When the mill produces annually about 50 tons of olive cake, the PtP is 63%, but if the quantity of olive cake produced increases until 1.000 tons, the probability to take part in a supply chain to produce animal feed by processing olive cake, increases too. We think that this aspect is may be due to the disposal cost for disposing olive cake. Even if this trend is the same in all Sicilian provinces, millers of Caltanissetta area are quite less willing to participate than other millers of the sample.

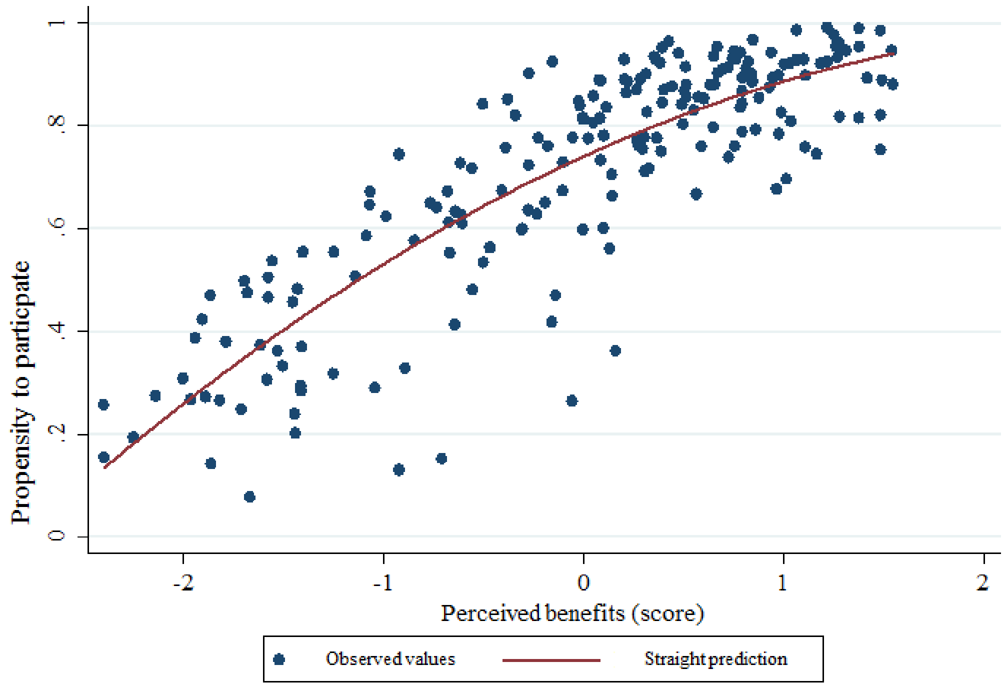
Figure 3.2. *The relation between the millers propensity to participate in a supply chain to valorise olive cake and the production of olive cake in different Sicilian areas.*



Some variables considered as "**previous experiences**" in the statistical model decrease the probability to participate. In particular, both the previous participation in a cooperative and the previous investments implemented decrease respectively of 17% and 12% (table 7) the probability to participate in the proposed new supply chain. This means that if interviewed not have participated in a cooperative and not have done previous investments, they are probably willing to take part in a supply chain. Our results are in line with a previous study that investigate the farmers' willingness to produce biomass (Cembalo et al., 2014), in fact the previous participation in a cooperative decreases the willingness to participate.

Finally, as for the **attitudes to collective action**, the only TPB factor significant is the miller's attitudes. Indeed, if expectations of olive oil producer are high, in other words, if he thinks that to valorise olive cake is better for him, the probability to participate in the supply chain is about 85%, while, on the contrary, the probability to participate decreases (51%) (graphs 2). Both social norms and the PBC are not significant in our model. However, social norms generally influence the interviewed propensity to take part in an eco-innovative supply chain (Wegener and Kelly, 2008; Cembalo et al., 2014).

Graphs 3.3. *Entrepreneur propensity to take part in a supply chain to valorise olive cake.*



The discussed model has analysed millers propensity to participate in a supply chain to valorise olive cake by producing animal feed.

3.4.3 Contract stated preferences

Data on millers' responses to the choice tasks have been analyzed with fixed parameters ($vh= 0$) and random parameters logit models. Results are reported in the table 10.

The upper part of the table shows results (fixed parameters logit) about contract characteristics preferred by interviewed. The "training meetings" is the only contract attribute that millers do not prefer. Indeed, the coefficient is not statistically significant (p=0.368). According to millers, the possibility to take part in the decisional phase of the supply chain, is not important. This result is not in line with previous outcome that evidences the propensity of farmers to participate in a bioenergetics supply chain, if this attribute is included in the contract (Cembalo et al., 2014). However, model results also evidence that olive oil producers seem to prefer a short contract with a growing base price, a minimum guarantee price, also with the possibility to extend the contract before its deadline (renegotiation option) and without the obligation of a minimum volume of production. The short duration of the contract, the growing base price, the presence of a minimum guarantee price and the "renegotiation option" are already considered significant contract attributes (Cembalo eta l., 2014b). The short contract duration could means that the "strategic" level of contract is rather scarce, since participant prefer a short relationship (Folkerts and Koehorst, 1997). Moreover, a recent study that has analysed contract attributes in a biomass supply chain for energy production (Wamisho Hossiso et al., 2017) confirms that the fixed price is particularly preferred by entrepreneurs when the length of contract is quite short (Wamisho Hossiso et al., 2017). In the sixth column of the table, it is possible to notice an economic quantification (for each tons of olive cake) of some contract attributes. Indeed, we can say that the minimum guarantee price attribute corresponds to 4~~,~~.8 € as premium price. On the contrary, the minimum volume of product is quantified in 5.1€. This means that millers prefer lost 5.1 euro for tons of product but they don't want the obligation to give a minimum volume of product. As for the attribute "renegotiation option", the premium price is in the amount of 3.3 € for each tons of olive cake. Furthermore, since interviewed prefer short contract, for every year added to the length of contract, the price of olive cake increases of 0~~,~~.86€ per tons of product.

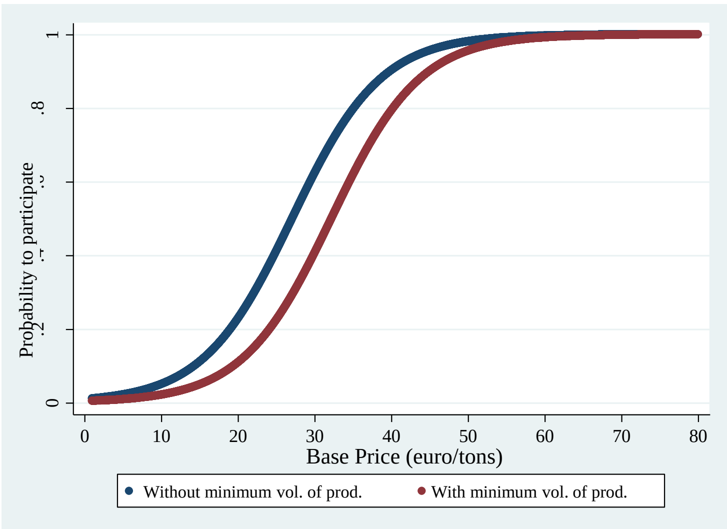
Table 3.10. Conditional logit results

Fixed parameters	Coef.	Std. Err.	Z	P>z	euros equivalent (€/ton)
Base price	0,172	0,033	5,21	0	
Minimum guarantee price	0,831	0,159	5,23	0	4,83
Length	-0,147	0,029	-5,07	0	-0,86
Renegotiation option	0,562	0,171	3,29	0,001	3,26
Training meetings	0,156	0,173	0,9	0,368	
Minimum volume of product	-0,882	0,176	-5,02	0	-5,12

Random parameters	M	Std. Err.	Z	P>z
Base price	0,343	0,056	6,16	0
Minimum guarantee price	0,923	0,206	4,47	0

Length	-0,400	0,075	-5,31	0
Renegotiation option	0,454	0,226	2,01	0,045
Trainings meeting	0,102	0,189	0,54	0,59
Minimum volume of product	-1,155	0,271	-4,25	0
Opt-out	11,269	2,011	5,6	0
	Σ	Std. Err	Z	P>z
Minimum guarantee price	-0,420	0,790	-0,53	0,595
Length	0,463	0,067	6,94	0
Renegotiation option	-1,584	0,380	-4,17	0
Minimum volume of product	1,472	0,398	3,7	0

Figure 3.4. *Probability to participate as function of base price and the presence or absence of minimum volume of production (olive cake).*



The previous graphs shows the positive relation between the probability to participate in an olive cake supply chain and the base price. If the base price per tons of olive cake increases, the willingness of the oil olive producers to join the supply chain increases too. In particular, a base price higher than 30euro/tons is needed to push the majority of the producers to participate. However, it is possible to highlight that the propensity to participate decreases if a minimum volume of product is required. This aspect could be also due to the not continuous olive cake production during the year and by the typical alternation of olives production.

The 29% of interviewee have not chosen any of the proposed contracts. The table below shows motivations about their no choice. The economic motivation prevails since most of them have stated that contract is not convenient (83%) and the 76% stated that "no price is convenient enough for changing". The 45% think that the olive cake valorisation is not a strategic option for millers, while somebody (38%) state that the contract length is too long. According to a consistent percentage

(62%) to participate in an olive cake supply chain is not convenient for millers but it is profitable only for animal feed companies that could gain too much power (41%). The lower percentage (29%) of millers that have not chosen any kind of contract have not trust in local millers.

Table 3.11 Motivations for respondents that have chosen no contract in any choice set

Statement	Does not reflect at all		→	Reflects perfectly	
	1	**2**	**3**	**4**	**5**
None contract is convenient	0.07	0.00	0.02	0.09	0.83
Olive cake valorisation is not a valid option for mill	0.09	0.17	0.07	0.22	0.45
Contracts duration is too long	0.07	0.05	0.29	0.21	0.38
Contracts are convenient only for animal feed company	0.05	0.03	0.10	0.19	0.62
Animal feed company could get too much power	0.09	0.05	0.19	0.26	0.41
Distrust in local millers to abide by contract terms	0.14	0.09	0.31	0.17	0.29
No price is convenient enough for changing	0.05	0.00	0.10	0.09	0.76

3.5 Conclusions and implications

The study relies on data collected in 2015 dealing with 201 Sicilian olive oil producers located in all Sicilian provinces: Agrigento, Caltanissetta, Catania, Enna, Messina, Palermo, Ragusa, Siracusa and Trapani. The descriptive analysis is conducted to investigate millers propensity to participate in the olive cake supply chain. In particular, a Probit model was applied to investigate the millers' willingness to participate in a supply chain to produce animal feed. Successively, by implementing a Conditional Logit model, millers' preferences about contract attributes were also defined. Outcomes show that the 71% of interviewed entrepreneurs have stated that they would to participate in an olive cake supply chain. The Probit model outcomes shown that the probability to participate in an olive cake supply chain increases when the quantity of olive cake produced increases too and decreases if interviewed has done previous investments and if he has already participated in a cooperative. Furthermore, miller's attitudes increases the propensity to take part in a supply chain to valorise olive cake. As for the contract attributes preferred by respondents, Conditional Logit results suggest that the "training meetings" attribute is not a significant attribute. Moreover, entrepreneurs prefer short contract with a growing base price, a minimum guarantee price, also with the possibility to extend the contract before its deadline (renegotiation option) and without the obligation of a minimum volume of production. These contract characteristics could be considered as determinants of the possible coordination in the olive cake supply chain. Moreover, results of the present study provides some preliminary information about the governance mechanisms to manage an olive cake supply chain. Our results are useful to implement an effective governance enhancing actors' participation, also by considering behavioural aspects, important element in a supply chain coordination process (Belaya and Hanf, 2012). The effectuated analysis identifies potential barriers to the creation of supply chain to produce animal feed by processing olive cake. Some relevant stated obstacles are often due to the scarcity of cooperation, and trust among potential participants in the supply chain. However, several authors have pointed out the importance of cooperation and trust in a bio-economy supply chain (de Besi an McCormick, 2015; Mohan, 2016). To enhance cooperation and trust, we have investigated also contract attributes. Finally, our results provide information about millers' preferences and suggest key contract attributes for managing an effective supply chain. Moreover, determinants and barriers we have evidenced represent important tools for local policy makers to gain, value creation both for stakeholders and citizen.

4 HOUSEHOLDS PERCEIVED EFFECTS OF BEAN AND BANANA MIXTURES OF VARIETIES ON YIELDS WITHIN UGANDA, EAST AFRICA

4.1 Introduction

The amount and nature of the food to be provided by the year 2050, when the human population is forecast to peak, is a matter of debate. Less contentious, however, is that even to maintain production of major staples will be difficult because of serious constraints like climate instability; impact of climate change on plant pests and diseases; and decline of non-renewable resources. At the same time, resources that are needed to mitigate and counter-balance these pressure factors are predicted to get scarcer and to rise in costs; and with the combination of these pressure factors, the stakes are high in the debates about which coping strategy is most appropriate for the future of agricultural production (Doring et al 2011).

In the recent decades, the increasing loss of crop diversity and specialization of cropping systems has led to a greater understanding of both academia and international organizations about the causes and consequences of this trend. The conventional understanding of the phenomenon is strictly connected to the industrial agricultural and the whole economic development (Finckh and Wolfe, 2006; Bellon *et al*., 2015): Farmers tend to cut down on crop diversity and specialize in monocultures because of the many private benefits they can get in line with the comparative advantage concept (de Vallavieille-Pope, 2004; Tooker and Frank, 2012). However, if positive outcomes are likely to occur in the short term, in the long term, the loss of diversity of species and their genetic variation as well as associated ecosystem services can have high costs to the society, and the farmer himself (Bellon *et al*., 2015). Monocultures facilitate the spread, multiplication and evolution of pests and diseases throughout the crops (Finckh and Wolfe, 2006). In such cropping systems, the decreased number of varieties; have limited resistance genes that can be overcome and thus the probability that a pathogen will spread and take over a farmers crops increases as the diversity and resistance of that same field decreases (de Vallavieille-Pope, 2004). Consequently, monocultures could negatively impact on food security and human nutrition, since they can lead to a decrease of the overall resilience of the agricultural systems in a world of increasing resource scarcity and climate change (Bellon *et al*., 2015). Generally, changes in the climate could potentially bring new pests in the agricultural system, whilst also making these pests more abundant when the temperature rises (Lin, 2011). Farmers commonly use pesticides to control pests and diseases and improve crop yields (de Vallavieille-Pope, 2004; Tooker and Frank, 2012). Combining pesticide use with appropriately improved commercial varieties of crop represents the standard practice in industrialized (high input) agriculture, but it usually lasts a short time before the pests and pathogens adapt and resurgence and multiplication occurs quickly (Buitatti and Ingram, 1991). Thus these chemicals are not a long-term sustainable solution as farmers will need to use consistently more and more of them to get the same results.

Furthermore, the large use of agricultural chemical products, specific for the intensive agriculture, is in contrast with the main goal of COP21, enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change (UNFCCC, 2015; Adamo, 2015). The latter also affects world food security and livelihoods (Hedger *et al.*, 2015). Hence, if intensive agriculture increases crop yields in the short run, in the long run, instead it generates several environmental problems (Mader *et al.*, 2002). At the same time, conservation agriculture is considered a panacea for environmental problems even if crop yields could decrease (Giller *et al.*, 2009). Agricultural strategies that could simultaneously support landscape resilience, greenhouse gas mitigation and rural livelihoods, may represent the best solution for sustainable rural development (Caracciolo & Lombardi, 2012; Bryan, 2013). Crop diversification is one strategy considered important in ensuring the resilience of agro-ecosystems (Lin, 2011). The mixture technique, one of the techniques of crop diversification, has been successfully used and well documented in pathogen management in several crops including wheat, common bean and rice (Wolfe and Finckh 1997; Finckhet al. 2000; Finckh and Wolfe 2006; Abate et al. 2000;Garrett and Mundt 1999; Mundt and Leonard 1986; Pyndji and Trutmann 1992; Zhu et al. 2000; Bowden et al. 2001, Ssekandi et al, 2015). Genetic mixtures provide an affective buffering effect to pest damage and a yield advantage (Ssekandi et al, 2015). Tooker and Frank, (2012) compared pest and disease incidence in monocultures and diverse mixtures, and found that the latter reduced pest damage whilst increasing yields. The benefits of diversity and mixtures are also seen in enhancing eco-system services (Tooker and Frank, 2012; Regmi *et al.*, 2016).

The principle behind growing mixtures over pure strands is to have resistant plants between the susceptible ones so as to slow down the spread of pests and diseases and to minimize losses in yield due to epidemics (Ssekandi at al., 2015; de Vallavieille-Pope, 2004; Hajjar et al., 2008). The proportion of resistant varieties in a mixture and the arrangement determines the effectiveness of mixtures in reducing the damage from particular pests and diseases (Ssekandi *et al.*, 2015). Mixtures of varieties or crops enhance resilience to climate change like drought and freezing and thus offer a greater yield stability as compared to pure strands (de Vallavieille-Pope, 2004). Close to 50% of wheat fields in Europe and tens of thousands of hectares of rice in China have been sown as cultivar mixtures (Zhu et al. 2000; Mundt 2002). In the United States, 18% of soft winter wheat planted in Washington State in 2000 and 7% of Kansas wheat planted in 2001 were cultivar mixtures (Bowden et al. 2001; Mundt 2002). These mixtures were typically constructed as random mixtures of five cultivars that vary in susceptibility to important diseases (e.g. rusts, powdery mildew), and yield nearly 30% better than monocultures when disease is present while maintaining yield, or even slightly improving it when disease is absent (Wolfe 1985; Martinelli, Brown & Wolfe 1993; Mundt 1994, 2002; Smithson & Lenne 1996; Garrett & Mundt 1999; Tooker and Frank, 2012).

Managing pests and diseases while ensuring resilience to climate change is more important for developing countries where agriculture is pivotal to rural development, alleviating poverty, improving livelihood options, and guarantying food security yet it is mainly characterized by poor access to markets and limited technologies (Utz, 2007). At the same time, production hinges on small farms therefore; there is a need to implement agricultural practices that improve crop yields while safeguarding the agricultural ecosystem (Sheppard et al., 2011). Indeed, pests and diseases cause the biggest loss of yield in East Africa, compared to other factors like drought and soil infertility (Bonabana-Wabbi, 2002). For instance in Uganda, the use of chemical products for managing pests and diseases, is not common because farmers often believe that the cost of purchasing these chemicals may not be worth the extra yields they garnish (Bekunda & Woomer, 1996; Mulumba, *et al.*, 2012). Since the chemical approach is not used that much, other strategies that can be used to reduce yield losses due to pests and diseases while ensuring higher resilience, and greater food and income security for farmers; need to be developed (Lin, 2011).

Non-chemical approaches for managing pests and diseases have been investigated for some of the important food crops in Uganda (Bonabana-Wabbi, 2002), like common bean (Ssekandi et al., 2015; Mulumba, et al. 2012) based on intra-specific crop diversity (crop varietal diversity) including the use of mixtures. Studies have shown that having diversity of varieties on farm reduces risk and vulnerability to pests and diseases (Mulumba et al., 2012; Zhu et al., 2000). Although previous studies have shown that mixtures reduce the damage caused by particular pests and diseases and increase yield (Olango et al 2016; Ssekandi et al 2015); the adoption of mixtures has not been steady fast. Therefore, this study carried out on both common bean and banana: assessed the factors that influence the adoption of mixtures by farmers for the two crops and the farmers' perceptions about the effects of mixtures on yields. The hypothesis of this paper is that crop mixtures could be considered a sustainable and long-term agriculture strategy.

4.2 The context: project and study sites

This study is a part of an ample research-for-development programme designed to improve pest and disease management, farmer resilience and crop productivity by increasing the use of crop genetic diversity at the local farm-level. In particular in the period between 2012 and 2015 an IFAD funded project was implemented by Bioversity International in partnership with the National Agriculture Research Organization in collaboration with academic and other government and non- government institutions[6] in Uganda, Morocco, Ecuador and China. Activities in Uganda were carried out in four sites with different ethnicities and ecological conditions. The study was conducted three sites namely, Nakaseke, Kabwohe and Rubaya. Nakaseke is located in central Uganda and is dominated by the Baganda ethnic group in the coffee-banana farming system. This site is in the Central Wooded Savannah agro-ecological zone with an altitudinal range of 1086-1280 masl, with an average rainfall of up to 1100mm and temperature ranging between 16 and 30 Celsius. Kabwohe is situated in western Uganda and is dominated by the Banyankole tribe, in a predominantly banana-cattle farming system. It is within the western medium-high farmlands agro-ecological zone with an altitude of 1400-1500 masl and rainfall up to 1100mm like Nakaseke. The temperatures in these two sites are between 12 and 28 degrees Celsius. Rubaya site is located in the south-western highlands of Uganda, with an altitude ranging between 1800-2200 masl, rainfall up to 1100 mm, and temperatures between 11 and 25 Celsius. Rubaya is dominated by the Bakiga ethnic group. The common bean assessment was done in the three sites while the banana assessment was only done in Nakaseke and Kabwohe sites. These sites were purposefully selected because farmers here they grow banana and/or common bean, and that there is high levels of diversity in the two crops.

4.2.1 Experimental design

The experimental design involved household surveys through which information from farmers was collected on: socio-demographic characteristics; varieties types and how they have been grown and changed over a period of five years; why farmers grow mixtures of varieties; what has been achieved from having many varieties on-farm; changes in yields in the five years and what led to these changes as well as the major pests and diseases and how they are being controlled. Households at each site were selected using a randomly stratified design (by village),

[6]The list of institutions in Uganda includes: PlantGenetic Resources Center of National Agriculture Research Laboratories of NARO , National Crops Resources Research Institute (NACCRI) of NARO), Makerere University and NAADS (National Agricultural Advisory Services) and Local Governments and others.

to ensure geographic representation across the four target villages within each agro-ecological site, totaling 240 households (60 households for common bean only from Rubaya site and 180 households for common bean and banana from Kabwohe and Nakaseke sites). During the household surveys, a deliberate effort was made to ensure that both male and female farmers were involved in equal numbers as respondents.

4.3 Empirical analysis and Results

4.3.1 Mixtures adoption

The analysis identified factors that influence the adoption of crop mixtures by farmers involved in the survey. We assumed that observable characteristics of the *i*-th farmer influenced i his or her choice of adopting mixtures in terms of the probability of mixtures adoption. Empirically, since we were investigating choices, a qualitative dependent variable approach was taken.

M_i^* is defined as stochastic variable that measure the propensity of the farmer to adopt variety mixtures. Propensity to adopt variety mixtures was not observed, but instead dichotomous variable was measured:

$$M_i = \begin{cases} 1 \text{ if } M_i^* > 0 \\ 0 \text{ if } M_i^* \leq 0 \end{cases} \qquad [4.1]$$

The propensity that the *i*-th farmer adopted variety mixtures depended on a set of *k* explanatory variables $\mathbf{x}_i$:

$$M_i^* = \mathbf{x_i}'\boldsymbol{\beta} + u_i \text{ i= 1, 2,… n.} \qquad [4.2]$$

Where $\boldsymbol{\beta}$ is a *k* vector of unknown parameters and u_i embodies the unobservable characteristics distributed by the standard logistic distribution. This formulation describes a conventional logistic regression model where β estimates can be obtained using maximum likelihood estimator (MLE).

Table 4.1. Description of variables used to assess mixtures adoption determinants

Variable name	*Type*	*Variable description*
M - Dependent Variable	Binary	Adoption of mixtures [1= yes; 0 = No]
d_age1	Binary	Age [1 if famers age >40 & < 61; 0 otherwise]
d_age2	Binary	Age [1 if famers age >60; 0 otherwise]
Gender	Binary	gender of respondent [1=Male 2=Female]
Householdsize	Continuous	the number of components in the household
Agr_income	Binary	the major source of income [1=crop farming, 0=other activity]

Cultivated_area	Continuous	total area cultived with bean & bananas (acres)
Belongtofarmergroup	Binary	participation to farmer group [1=yes, 2=no]
site_1	Binary	geographical area where the household is [1=Nakaseke; 0 otherwise]
site_2	Binary	geographical area where the household is [1= Kabwohe; 0 otherwise]
Ban_producer	Binary	Producer of bananas [1= yes; 0 = No]
Bean&ban	Binary	Joint producer of Bananas & Beans [1= yes; 0 = No]

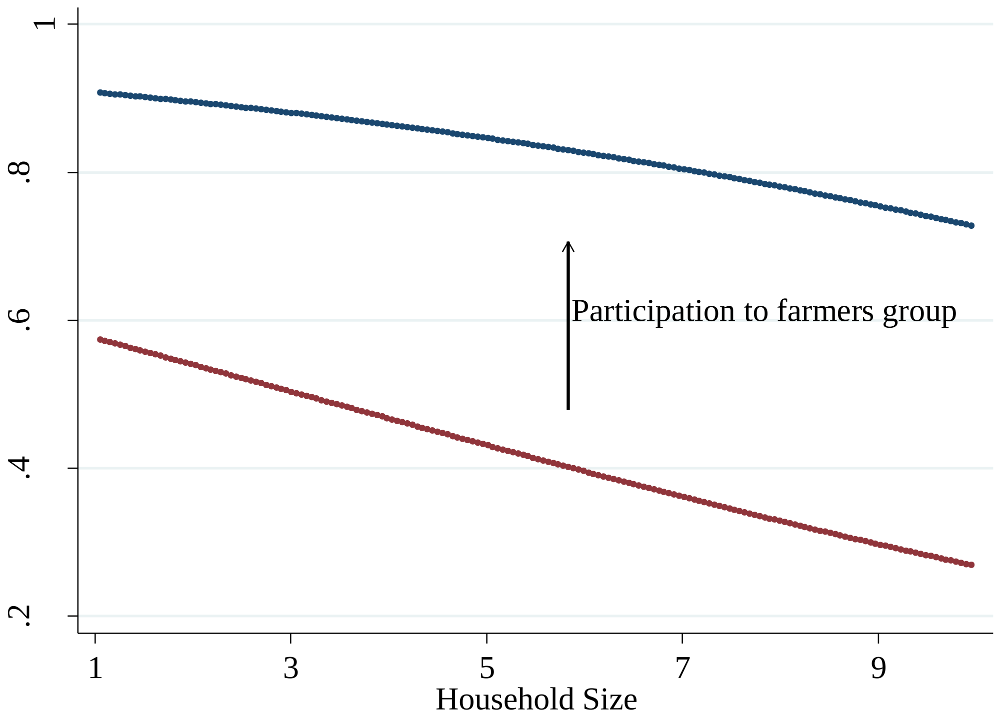
Results of the analysis on factors affecting farmers' decisions to adopt mixtures are reported in the table 4.2.

Table 4.2. Factors affecting mixtures adoption. Logit estimate

Variable	*Coef.*	*Std.dev*	*p-value*	
d_age1	0.421	0.450	0.350	
d_age2	1.107	0.781	0.156	
Gender	0.701	0.433	0.106	
Household Size	-0.146	0.078	0.062	*
Agr_income	1.744	0.830	0.036	**
Cultivated_area	0.083	0.228	0.716	
Belongtofarmergroup	1.983	1.067	0.063	*
site_1	-1.087	0.897	0.225	
site_2	0.144	0.964	0.882	
Ban_producer	2.661	1.590	0.094	*
bean&ban	-0.097	1.526	0.949	
_cons	-4.061	1.888	0.031	**

The size of the household, negatively and significantly affected the farmer' decision to adopt mixtures. Age and gender of household head did not affect its propensity to adopt varietal mixtures. Participation in a farmers group had a positive influence on the decision to adopt mixtures (Figure 1). In addition, a greater propensity to adopt mixtures was observed among households that are mainly dependent on agriculture for their incomes, and in households that are producers of bananas. Location and size of the farm (in terms of total area cultivated) did not affect significantly the mixtures adoption.

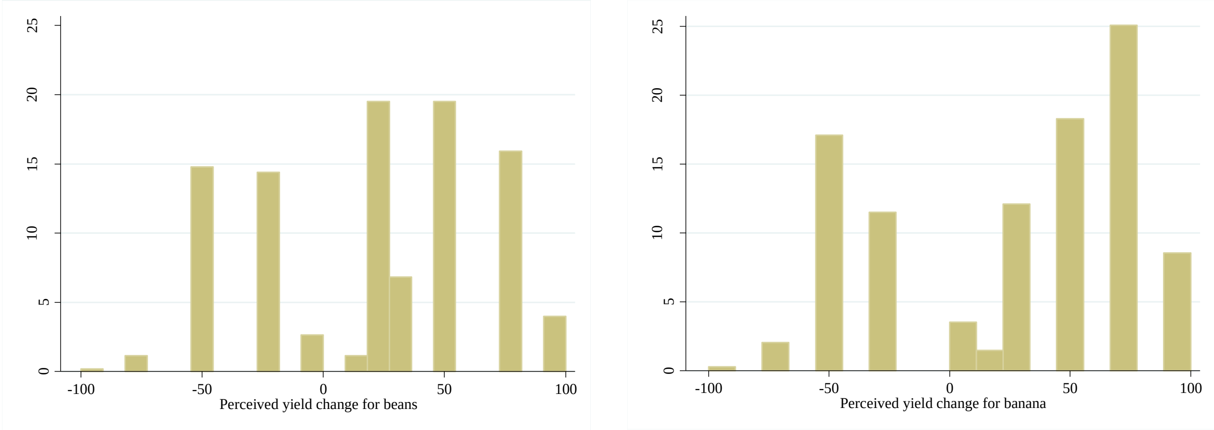
Figure 4.1 *The effect of household size and participation in a farmers group on mixtures adoption decision*



4.3.2 Effect of mixtures on perceived yield.

The impact of the mixtures adoption on the farmer perceived yield change (PYC) was analysed. Information on the *i*-th farmer PYC on the last one, three and five years was collected using the following questions; "*Have your yields (productivity) increased or decreased over the last one, three and five years? and by what percentage has your bean or banana yield increased/ decreased?*" Respondents could answer by indicating an increase or a decrease and then quantifying the perceived yield change using a scale ranging from 1 to 5 (1=None; 2=1-25%; 3= 26-50%; 4=51-75%; 5=76-100%). This data was used to build a continuous latent variable of perceived yield change, PYC_i ranging from -100% to +100%. The farmer perceived yield change was indexed by time, PYC_{it} (t = 1,3,5) since each *i*-respondent indicated the perceived change of yield over three different time spans (last year, three and five years).

Figure 4.2 *Frequency distribution of perceived yield change (%) for Beans (left) and Banana (right)*



The observed variability in farmers PYC (Figure 2) was modelled as a linear function of m households time-invariant characteristics $\mathbf{x_i}$ (including household head age, gender, size, participation to farmers group, residence, number of years growing bean or banana, cultivated land area for bean or banana, the simultaneous presence of both bean and banana) and n time variant cropping systems characteristics ($\mathbf{z}_{it}$) such as the number of used varieties of bean and banana, the incidence of improved varieties over the total employed and the incidence of varieties that were cultivated as varietal mixtures over the total varieties used. The latter variable was interpreted as a proxy of the degree of the commitment of the farmer to the adoption of varietal mixtures. The higher this value was, the greater was the use of mixtures by the farmer. Since the observed variability in farmers PYC could depend on time-dependent unobservable characteristics, time varying fixed effects ($\mathbf{T}_t$) were included.

The linear relation function for PYC_{it} was written as follows:

$$PYC_{it} = \alpha + \mathbf{x_i}'\boldsymbol{\beta} + \mathbf{z}_{it}'\boldsymbol{\gamma} + \mathbf{T_t}'\boldsymbol{\theta} + u_{it} \quad i= 1, 2,\dots n;\ t = 1,3,5. \qquad [4.3]$$

Where α is the intercept of the equation, $\boldsymbol{\beta}, \boldsymbol{\gamma}$ are respectively m and n vectors of unknown parameters to be estimated, representing the marginal effect of the explanatory variables on the PYC, $\boldsymbol{\theta}$ vector controls time-dependent unobservable characteristics, while u_{it} is the error term including the unobservable part of PYC_{it}. This model tested the hypothesis that the source of the observed variation of farmers PYC could be explained by the intensity of mixtures adoption measured as incidence of varieties that were cultivated as varietal mixtures over the total varieties. In order to identify some possible interactions between factors affecting adoption of mixtures on PYC, incidence of varieties in mixtures with the cultivated area, incidence of local varieties and years spent cultivating the crop; were finally added. Equation 3 was used for analysing PYC of both beans and bananas. Table 3 below shows the descriptive statistics of the variables included in the two models.

Table 4.4 reports the two Ordinary Least Squares (OLS) estimates. For both beans and bananas, incidence of varieties in mixtures positively and significantly affected the PYC. γ parameters of

3.85 and 11.09 indicated the average change in the percentage of perceived yield respectively for beans and bananas per year, in the case that the total varieties were used as mixtures. For instance, the observed average incidence of varieties in mixtures was 0.45 for beans and 0.86 for bananas and the impact of mixtures was estimated to increase yield in a period of three years equivalent to 3×0.45×3.85 =5.2% for beans and 3×0.86 ×11.09=28.6% for bananas.

Table 4.3. Descriptive statistics of the variables included in the two equations

	Bean[a]				Banana[b]			
Variable	Mean	Std.dev	Min	Max	Mean	Std.dev	Min	Max
Perceived Yield Change (%)	20.48	45.90	-100	100	26.25	53.03	-100	100
d_age1	0.45	N.A	0	1	0.45	N.A	0	1
d_age2	0.15	N.A	0	1	0.18	N.A	0	1
Gender	1.60	N.A	1	2	1.63	N.A	1	2
Household Size	6.46	2.89	1	24	7.20	3.11	1	24
Agr_income	0.93	N.A	0	1	0.95	N.A	0	1
Cultivated_area	0.81	0.61	0	4	1.54	1.45	0.13	7
Belongtofarmergroup					1.05	0.21	1	2
Bean&ban	0.61	N.A	0	1	0.97	N.A	0	1
Site_1 [1=Nakaseke; 0 otherwise]	0.32	N.A	0	1	0.46	N.A	0	1
Site_2 [1= Kabwohe; 0 otherwise]	0.34	N.A	0	1	0.54	N.A	0	1
Site_3 [1= Rubaya; 0 otherwise]	0.34	N.A	0	1				
Past experience (years cultivating the crop)	21.31	14.36	0	60	21.51	14.98	0	60
sh_mixtures	0.45	0.42	0	1	0.86	0.25	0	1
sh_localvarieties	0.46	0.36	0	1	0.52	0.32	0	1
total_varieties	3.97	2.06	1	12	6.11	2.64	2	16

[a]*#Sample size 172*; [b]*#Sample size 108*;

Other significant determinants of PYC for beans were: total area under cultivation, participation in a farmers group; both influencing positively the PYC and the location (Households located in Kabwohe and Rubaya experienced lower yields change compared to those located in Nakaseke). About 20% increase of the yield with the respect to a period of five years was imputed for time-dependent unobservable characteristics that were indicated in the model as ϴ parameters.

For banana, other significant determinants of PYC were: households head in the age range between 40 and 61 years old experienced higher PYC (+18.1%) compared to the others; location where farmers located in Kabwohe reported a lower PYC compared to those living in the other regions (-22.8%).

Table 4.4. Determinants of Perceived yield change (%) for Beans and Banana – OLS estimates

	Beans[a]				Banana[b]			
	Coef.	Std.dev[*]	*t*-stat	*p*-value	Coef.	Std.dev[*]	*t*-stat	*p*-value
β *parameters*								
d_age1	1.18	4.97	0.24	0.813	**18.81**	**7.14**	**2.64**	**0.009**
d_age2	5.49	8.82	0.62	0.534	15.17	10.01	1.52	0.131
Gender	-2.95	4.14	-0.71	0.477	9.73	6.38	1.52	0.128
Household Size	-0.30	0.86	-0.35	0.724	-0.42	0.96	-0.44	0.659
Agr_income	-8.40	6.92	-1.21	0.226	-10.02	13.46	-0.74	0.457
Cultivated_area	**13.87**	**5.19**	**2.67**	**0.008**	12.61	11.27	1.12	0.264
Belongtofarmergroup	**20.31**	**6.50**	**3.12**	**0.002**	-6.19	14.19	-0.44	0.663
bean&ban	-17.07	11.51	-1.48	0.139	-8.00	16.78	-0.48	0.634
Past experience (years cultivating the crop)	-0.04	0.24	-0.16	0.869	0.25	0.66	0.38	0.706
Site_2	**-15.21**	**6.83**	**-2.23**	**0.026**	**-22.76**	**7.76**	**-2.93**	**0.004**
Site_3	**-26.77**	**11.80**	**-2.27**	**0.024**				
γ *parameters*								
sh_mixtures (incidence of varieties in mixt.)	**3.85**	**2.13**	**1.81**	**0.071**	**11.09**	**4.83**	**2.3**	**0.022**
sh_locvarieties (incidence of loc. var.)	1.60	1.82	0.88	0.378	1.00	3.58	0.28	0.779
total_varieties (total # of varieties)	-0.35	0.29	-1.24	0.215	-0.42	0.39	-1.09	0.278
Interaction terms								
sh_mixtures × sh_loc. Varieties	-0.92	11.21	-0.08	0.935	**-36.39**	**15.16**	**-2.4**	**0.017**
sh_mixtures × Cultivated Area	-1.93	7.67	-0.25	0.801	-3.33	11.74	-0.28	0.777
sh_mixtures × Past experience	-0.40	0.30	-1.32	0.186	-1.06	0.68	-1.55	0.122
θ *parameters*								
T_3	9.25	6.01	1.54	0.125	-7.36	12.97	-0.57	0.571
T_5	**20.95**	**7.51**	**2.79**	**0.005**	-24.61	22.80	-1.08	0.281
A	17.70	18.02	0.98	0.326	**51.94**	**31.21**	**1.66**	**0.097**

[a] N= 516, R^2= 0.12. [b] N= 324, R^2= 0.16. [*] Robust standard errors clustered at the household level to account for the fact that households are represented thrice in the data.

4.4 Discussion

4.4.1 Factors that affected the adoption of mixtures

This study has revealed that a number of factors influence the farmers' decision to grow mixtures of common bean and banana. Participation in a farmers group had a positive influence on the decision to adopt mixtures (Figure 1) and this could be attributed to the fact that in farmers groups, there could be exchange and sharing of knowledge, experiences about the value of growing mixtures thereby influencing member farmers to adopt the technique. According to the study by Mwaura (2014), membership to farmer groups was observed to lead to achievement of higher yields for banana in Uganda. This is consistent with results of other studies, where group extension had been associated with superior yields (Godtland et al.,2004). Furthermore, this result confirms that to share ideas and experiences is important to enhance cooperation (de Besi and McCormick, 2015) and to follow the long term goals (Mohan, 2016). In addition, a greater propensity to adopt mixtures was observed among households that are mainly dependent on agriculture for their incomes as these could be putting all their efforts in understanding what techniques do work well so that they get the best out of the efforts they put into agriculture whereas those who are not purely dependent on agriculture may not mind much because they can look elsewhere for survival. Households that are producers of bananas were more likely to adopt mixtures than those growing beans possibly because traditionally, banana growing in Uganda has been done in mixtures (Nantale et al, 2008) and even the commercialization of bananas has not changed much this practice yet the commercialization of beans is leading to the neglection of growing mixtures of late. Location and size of the farm (in terms of total area cultivated) did not affect significantly the mixtures adoption. This could imply that mixtures can still be employed regardless of where the farm is located and regardless of its area of coverage. This is contrary to findings by Andow (1991) Baggen &Gurr (1998) that effectiveness of plant species diversity approaches can be inconsistent and context dependent. The size of the household, negatively and significantly affected the farmer' decision to adopt mixtures. This could be explained by the fact that members of a household provide farm labour in Uganda and with many members, a household can afford to cultivate a bigger area of land and can therefore afford to allocate each variety of a crop to a particular area of land without mixing them.

Age and gender of household head did not affect its propensity to adopt varietal mixtures possibly because awareness about the importance of mixtures and their necessity does not depend on gender and age. According to the findings by Asiedu-Darko (2014), gender had no significant effect on the adoption of agricultural technologies in Ghana while age correlated negatively with adoption with older farmers more likely to stick to use of traditional farming methods whereas younger farmers prefer use of modern methods of farming. However age was found to positively influence adoption of sorghum in Burkina Faso (Adesiina and Baidu-Forson, 1995), therefore the relationship between age and adoption of agricultural technology varies with the type of technology being introduced (Asiedu-Darko, 2014). In line with this, is the recognition that increasing plant species diversity often entails considerable logistical and/or economic challenges. For example, growing more than one crop or variety in a single field may not be compatible with modern agricultural equipment. Thus, with questionable economic benefits and considerable challenges, techniques to increase plant diversity may be rarely implemented by some growers (Letourneau et al. 2011; Lin 2011: Tooker and Frank, 2012).

However, logistics associated with mixtures (i.e. mixing seeds, harvesting, marketing) have not hindered production, particularly with small grains where cultivar mixtures have been most popular (Mundt 2002: Tooker and Frank 2012).

4.4.2 Effect of mixtures on perceived yield change

For both beans and bananas, incidence of varieties in mixtures positively and significantly affected the perceived yield change (PYC). This is in agreement with Doring et al (2011) who observed that the risk of low yields decreases by using the mixture and this advantage is more pronounced under the higher variability conditions, as one genotype fails, another one compensates for the failure. The genotype diversity provides insurance against environmental fluctuations. The observed average incidence of varieties in mixtures was 0.45 for beans and 0.86 for bananas and the impact of mixtures was estimated to increase yield in a period of three years equivalent to 3×0.45×3.85 =5.2% for beans and 3×0.86 ×11.09=28.6% for bananas. The difference in the two percentages could imply that there are differences in the diffusion of mixtures among the two crops but this requires a validation study. Earlier studies do confirm that bananas and beans have been intercropped for quite some time in Uganda, but each crop is maintained as a mixture of different genotypes in farmers' fields (Nantale et al., 2008, Mulumba et al 2012).

Other significant determinants of PYC for beans included total area under cultivation which implies that the bigger the area that was planted with common bean mixtures, the greater the yields. Participation in a farmers group also influenced positively the PYC for common bean and this could still be attributed to the awareness and the practical knowledge acquired through groups about employing mixtures properly, thereby enabling the farmers to realize increased yields. The location significantly determined the PYC in that households located in Kabwohe and Rubaya experienced lower yields change compared to those located in Nakaseke. This could be attributed to many factors including the compatibility of the genotypes put in the mixtures, the management accorded to them and the climatic conditions of particular sites, among others. This is in agreement with the findings by Andow (1991) Baggen &Gurr (1998) that effectiveness of plant species diversity approaches can be inconsistent and context dependent. It was also noted by Wilhoit (1992) that cultivar mixtures appear to have many benefits and, as long as varieties have similar agronomic characteristics, should not require farmers to change production practices such as planting and harvesting time and do not require any economic investment in new equipment.

Significant determinants of PYC for banana included the households head in the age range between 40 and 61 years old who showed a higher PYC (+18.1%) compared to the other age groups. This can be attributed to the practical knowledge and experience that makes this age group perfect the art and science of managing the mixtures to get the best out of them. The study by Edmiades et al (2006) realized positive associations between the age of the plantation and both variety and use group diversity. The older the plantation, the longer the time span families have had to accumulate diverse banana types within and over generations of managers. Farmers' location also influenced the PYC whereby farmers located in Kabwohe reported a lower PYC compared to those living in the other regions (-22.8%). This could be attributed to the fact that farmers in Kabwohe are better managers of banana plantations compared to those of Nakaseke and it being that all plantations are in mixtures and properly managed, the yields are somehow not changing much yet in Nakaseke, the farmers who improve their management techniques notice a big change in yields.

4.5 Conclusion

This study has confirmed further, the importance of crop varietal mixtures in improving yields, according to the modelled increase in yields of common bean and banana varietal mixtures of 5.2% and 28.6% respectively, for each year. This is in addition to enhancing ecosystem services and saving the money that would be put to purchasing chemicals to control pests and diseases. Additionally, results have shown that awareness about the importance of crop varietal mixtures as well as the practicability and knowledge of applying them are crucial for their adoption as seen from the influence of the membership to farmer groups and the age of farmers; on adoption of mixtures. Location and size of the farm (in terms of total area cultivated) did not affect significantly the mixtures adoption. This could imply that mixtures can still be employed regardless of where the farm is located and the size of farm. However location significantly determined the Percieved Yield Change (PYC) which calls for more research into mixtures suitability for particular contexts in respect to the compatibility of the genotypes, suitable management practices and most appropriate acreage for maximum impact. The positive effects of bean and banana mixtures on yields (respectively 5.2% and 28.6% for each year) confirm that mixtures bean and banana varieties could be considered an effective bio-economy strategy. Countries' adopting policies and strategies that minimize barriers to mixtures adoption could go a long way in achieving sustainable development thereby reducing use of agricultural chemical products which are in contrast with the main goal of COP21; enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change (UNFCCC, 2015; Adamo, 2015).

5 SUMMARY OF THE MAIN FINDINGS

During last years, bio-economy has gained more scientific attention (EC, 2012; McCormick and Kautto, 2013; Von Braun, 2013). In particular, bio-economy strategies are considered effective tools to provide the use of renewable natural resources (reducing GHG emissions) and, simultaneously, to improve biodiversity, environment resilience and food security (EC, 2012). However, as stated above, the implementation of bio-economy strategies is characterized by several barriers (de Besi and McCormick, 2015; Van Lancker, 2016). This work has investigated the bio-economy strategy implementation in developed and developing countries. In particular, three different case studies were analysed, whereof two based on the use of agricultural by-products (Sicily, Italy) while, the last one has regarded an agricultural strategy cultivation in Uganda (Africa).

As for the agricultural by-products valorisation, some of citrus and olive oil production by-products (the so-called "pastazzo" and the olive cake, respectively) have been considered. Agricultural by-products valorisation generates the energy and products with added value production and also a more efficient management of wastes (FAO, 2013). One benefit related to processing by-products could be the reduction of environmental, economic and social issues, since it creates economic value for farmers and social benefits for citizen (Marotta and Nazzaro, 2011). However, as discussed above, there are still several barriers such as the lack of cooperation and integration in the supply chains. In the present thesis, pastazzo and olive cake supply chain have been investigated. Contract attributes preferred by interviewed entrepreneurs have been explored with the aim to point out determinants and barriers of one of the most important cooperation mechanism (i.e. the contract) of supply chains (Handayati et al., 2015).

On the other hand, the crop mixtures cultivation (the third case study) can also be considered as a bio-economy strategy, since cultivation of several varieties (mixtures), such as bean and banana, increases the yield by using the same quantity of input (e.g. soil, water and so on). At the same time, the cultivation of mixtures preserves the environmental resilience, and reduces environmental impact including GHG emissions by decreasing the use of chemical inputs with direct benefits for the society (Lopez et al., 2013). Determinants and barriers for the mixture adoption were also explored.

The present thesis emphasizes that it is possible to implement bio-economy strategies both in developed and developing countries. Indeed, in developed countries the advanced innovation technologies allow to transform agricultural wastes or by-products in products with added value. Nevertheless, in developing countries, where the innovation is not so widespread, bio-economy strategies adoption is possible too. As for by-products supply chain, determinants and obstacles to adopt effective strategies in order to valorise pastazzo and olive cake were been highlight. Moreover, both for pastazzo and olive cake case studies, stakeholders' preferences about specific contract attributes were evidenced. As for the bean and banana mixtures adoption, the case study has shown that some farmers and farms' aspects could decrease/increase the propensity to adopt mixtures cultivation.

Obtained results could be useful to policy makers to promote bio-economy strategies adoption by eliminating barriers evidenced in this thesis and supporting the diffusion of factors that increase the propensity to implement a bio-economy strategy.

Anyway, future research could introduce also environmental and social indicators to quantify the impact of bio-economy strategies in term of environmental and social sustainability to identify the trade-off among environmental, economic and social effects, thus rendering the bio-economy strategy an effective tool to "making virtue out of necessity" (Von Braun, 2013).

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